The LHCb VELO Upgrade

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On Behalf of the LHCb VELO Upgrade

29/05/18

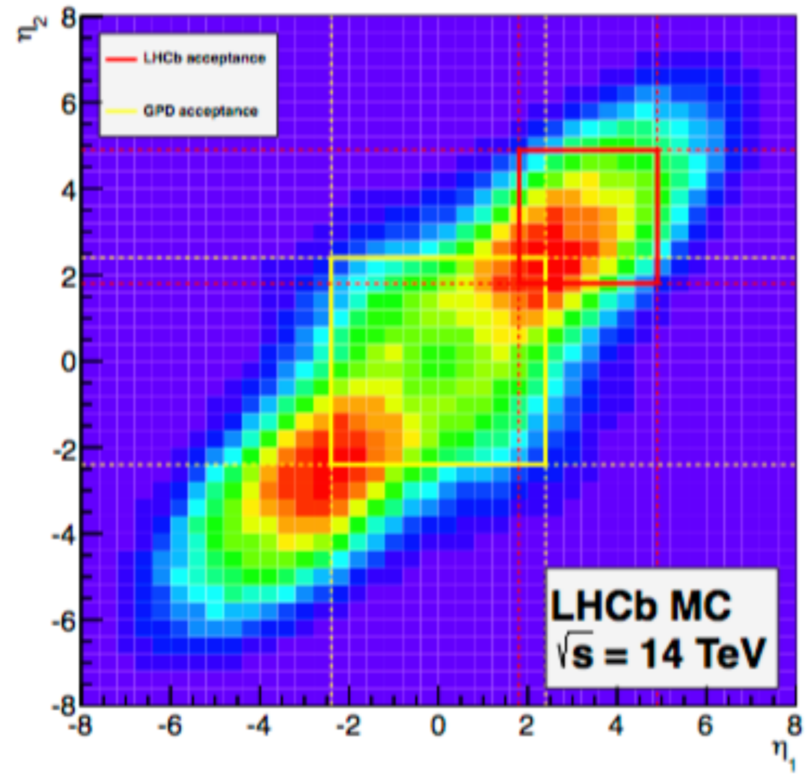
LHCb Detector

Heavy Flavour Experiment

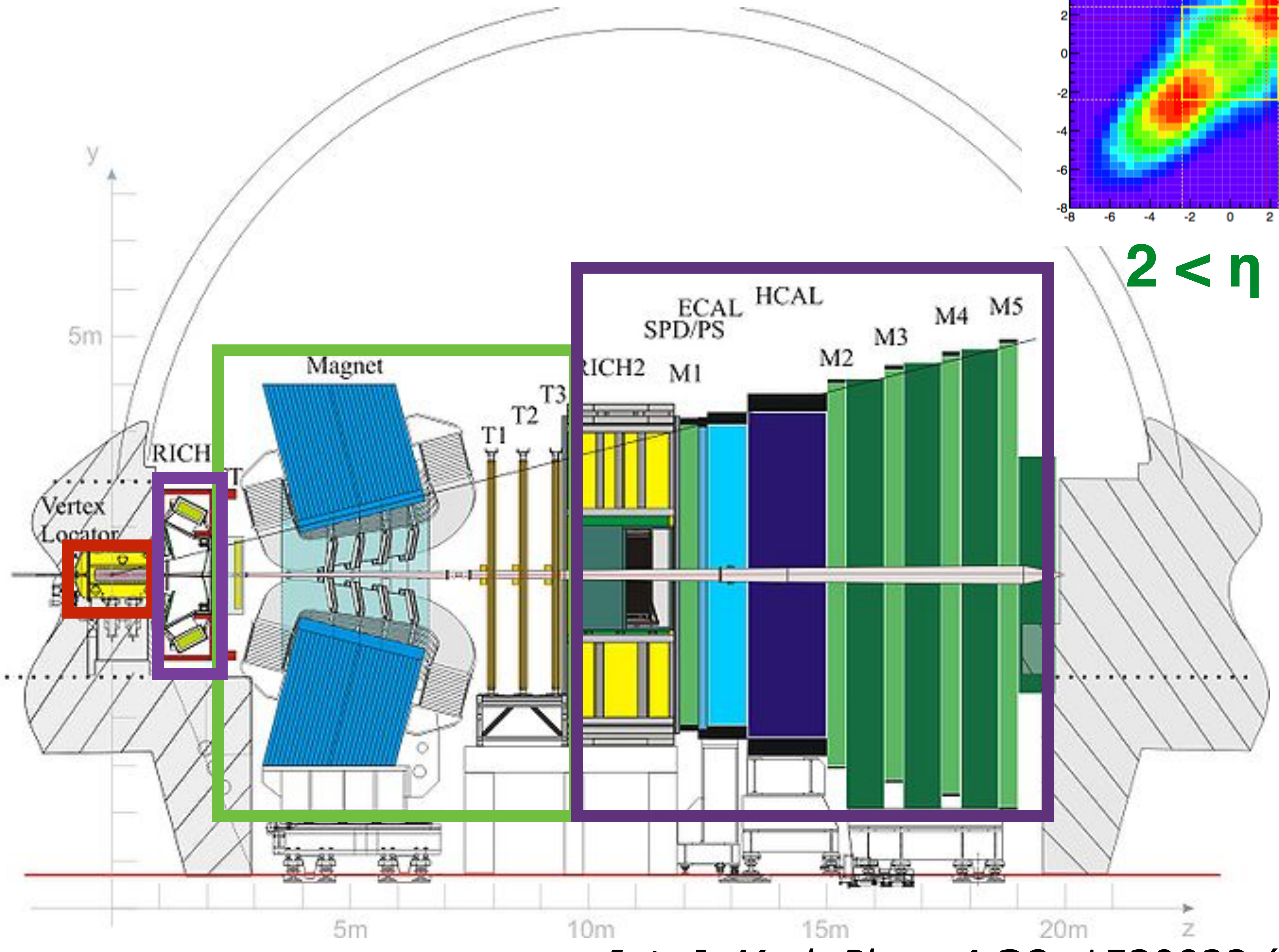
Precise vertex reconstruction

Tracking and momentum resolution

Particle identification capabilities



$2 < \eta < 5$



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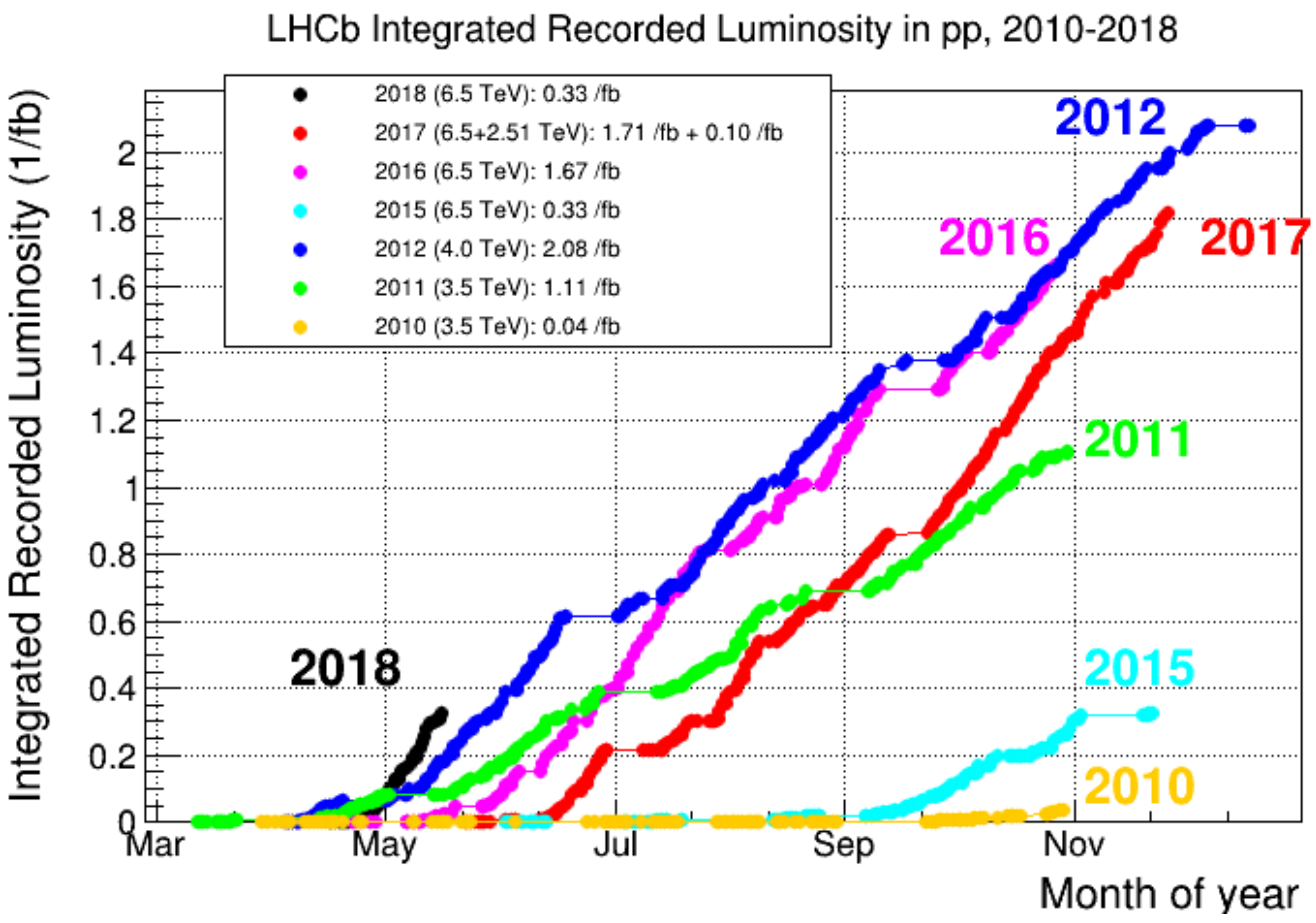
LHCb Detector Upgrade



By the end of Run II many analysis become statistically limited.

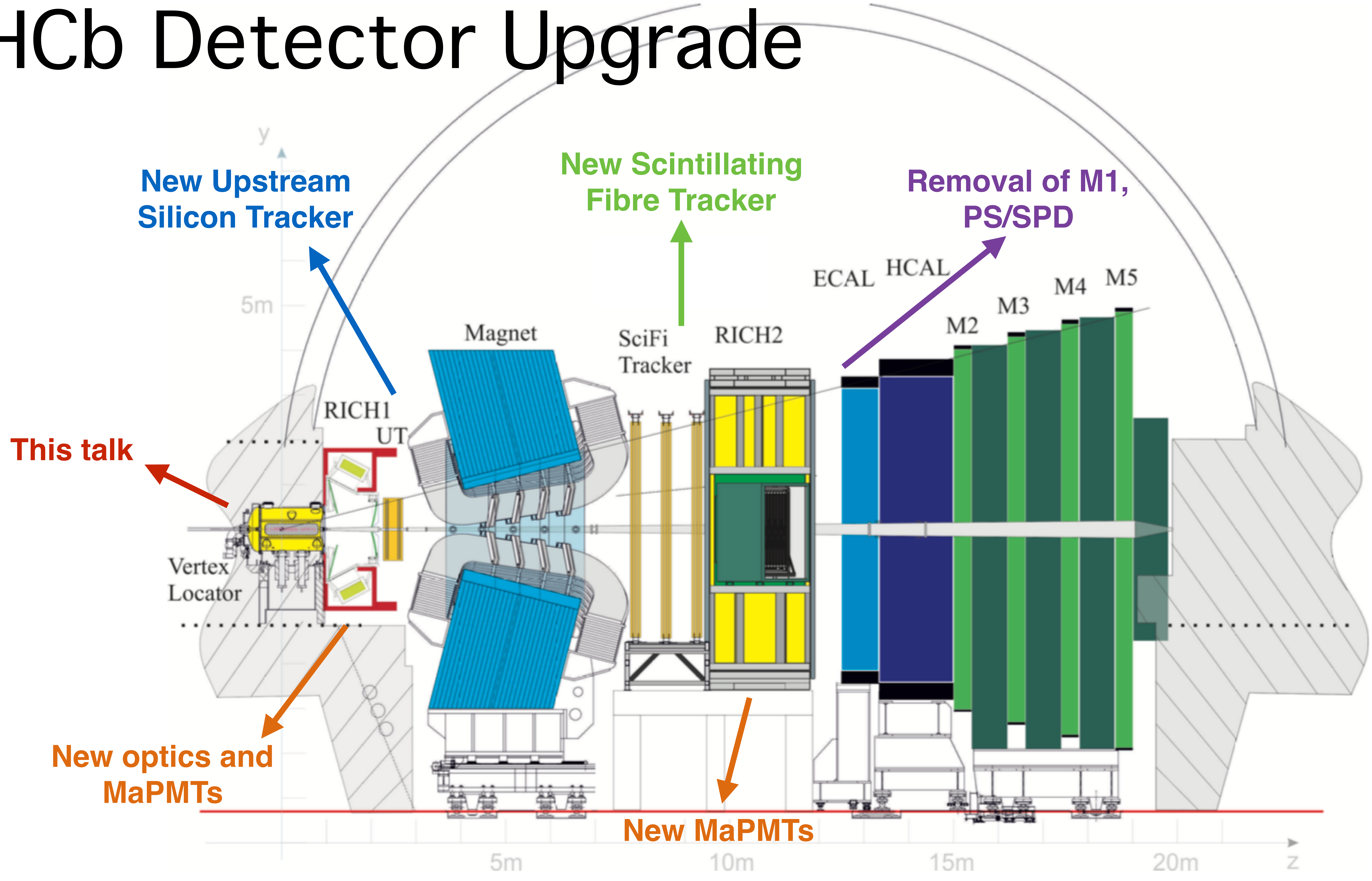
Increasing Luminosity in order to achieve 50fb^{-1} in Run III.

4×10^{32} cm^{-2}s^{-1} → 20×10^{32}cm^{-2}s^{-1}

Upgrade Trigger implemented on software only.

Readout: 1 MHz → 40 MHz

LHCb Detector Upgrade



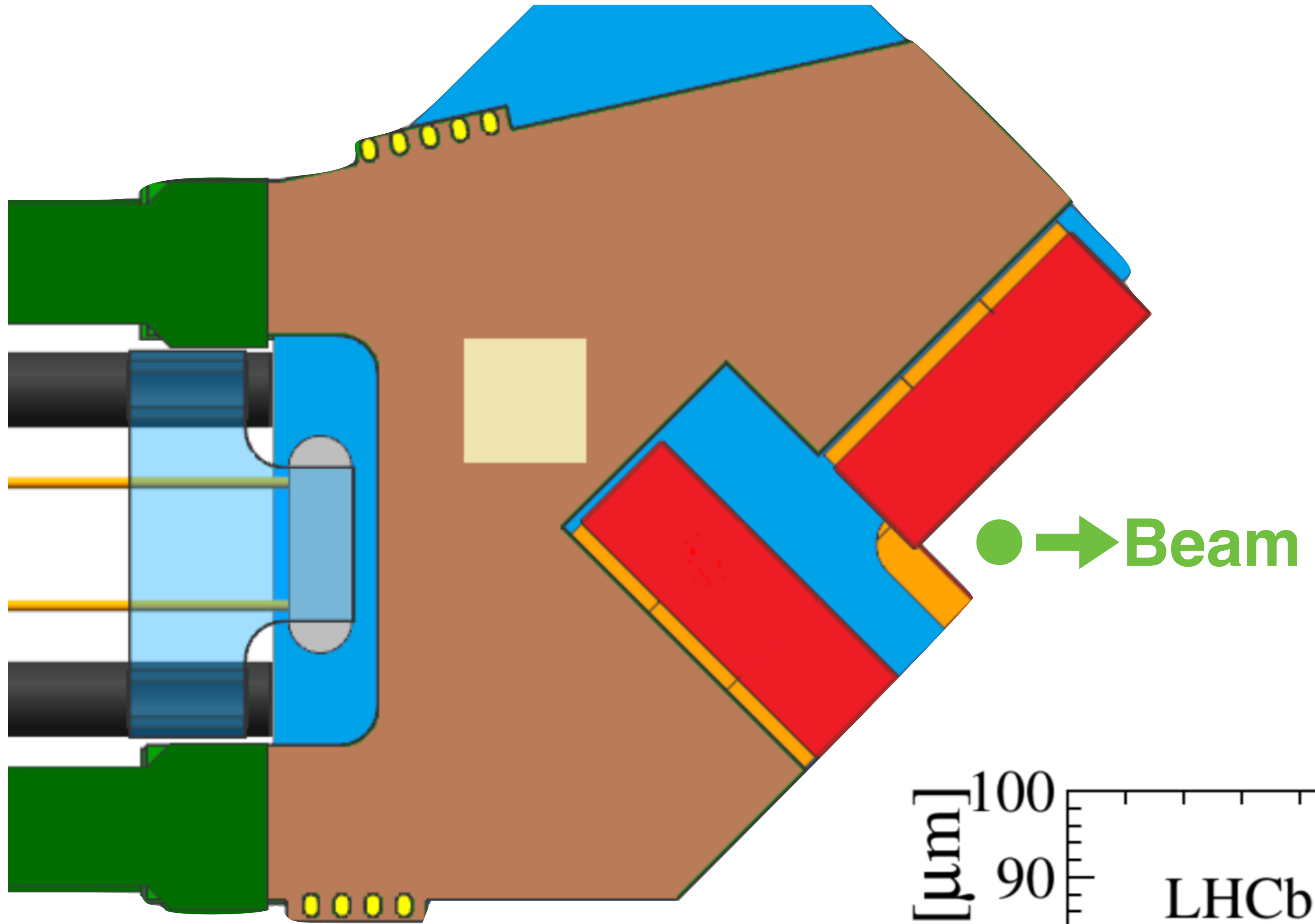
The VELO Upgrade

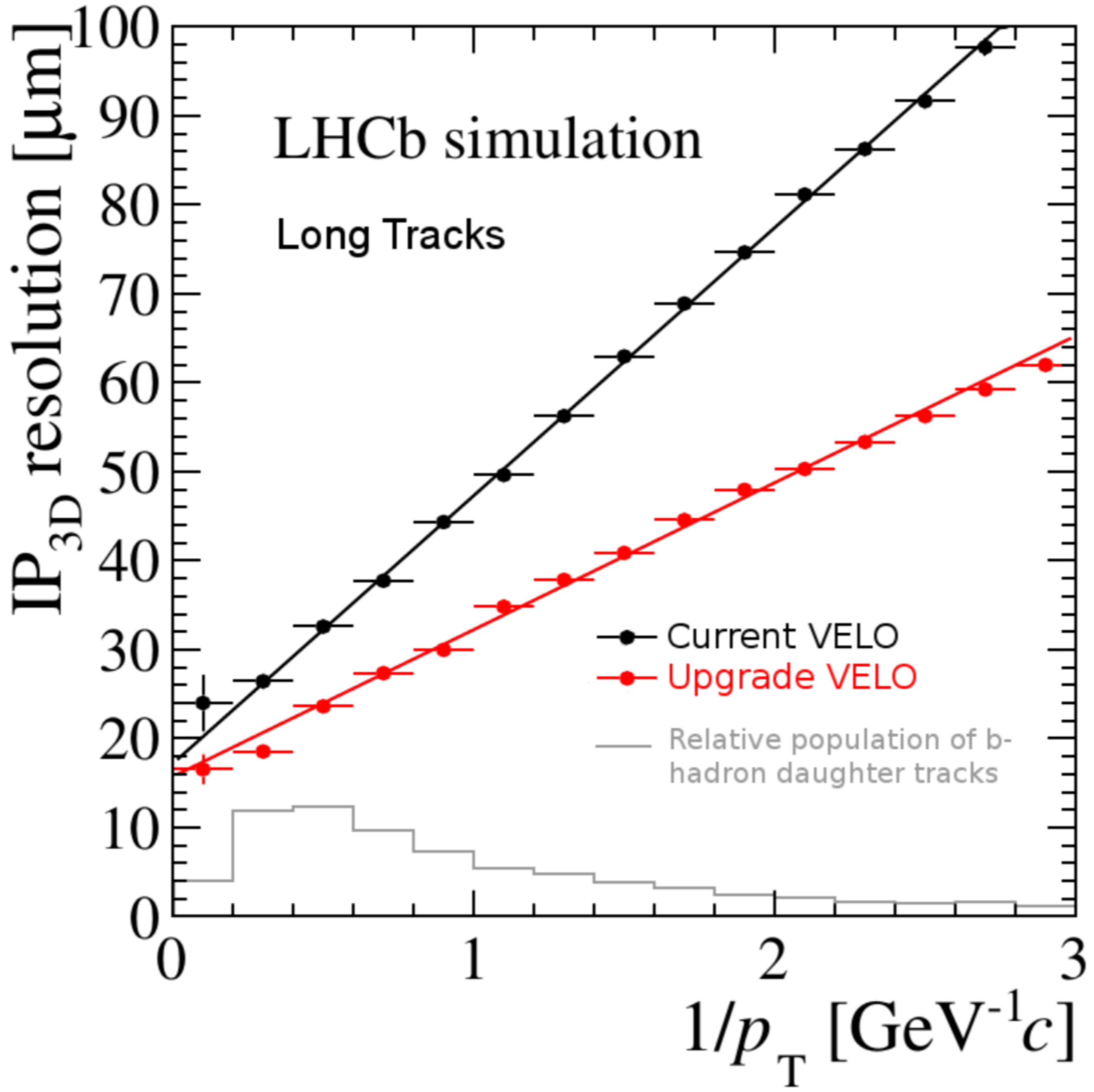
Full 40 MHz readout, Luminosity 5x Higher.

Change from Silicon Microstrips to Hybrid Pixel Detector.

Data Bandwidth of 20 Gbit/s for central ASICS.

Microchannel CO_2 cooling, sensor temperature <-20°C





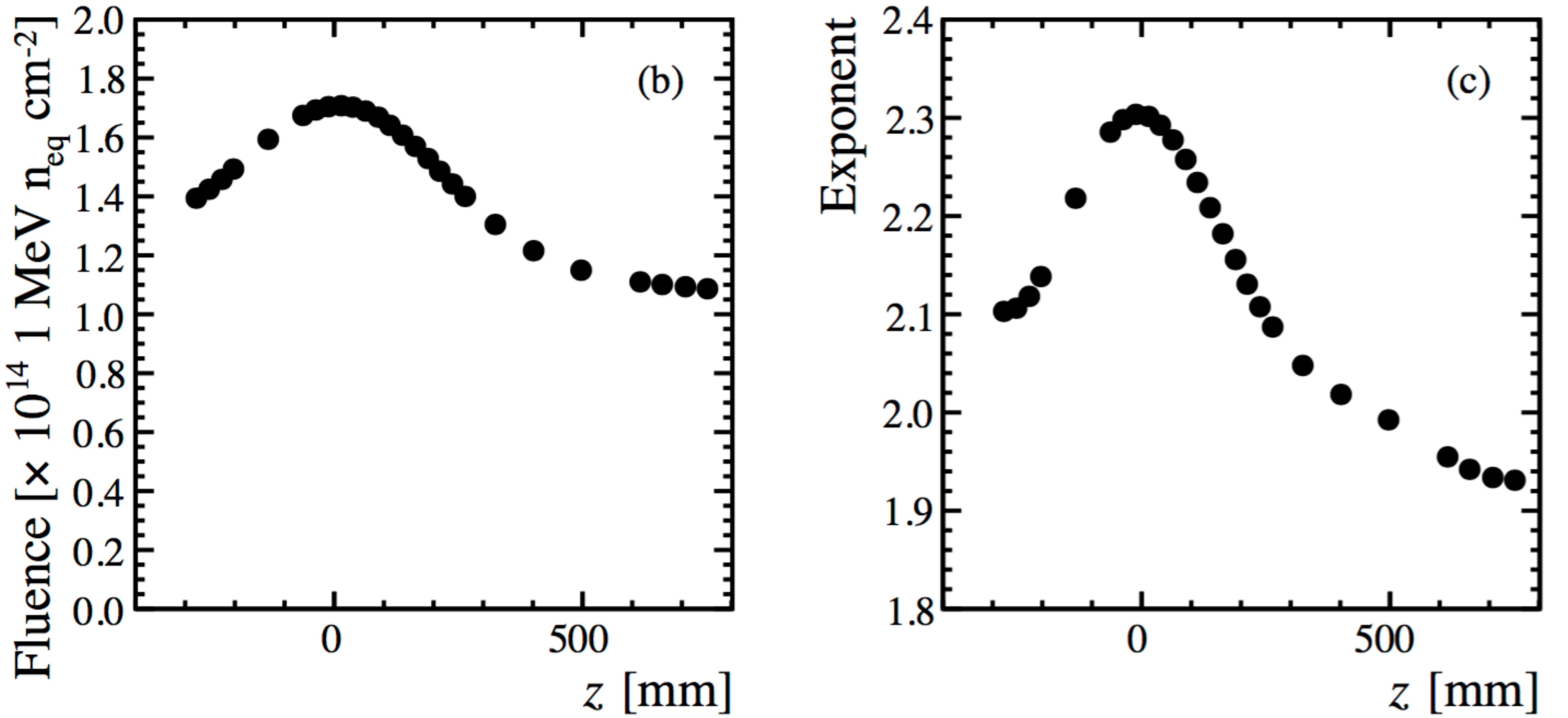
VELO Upgrade

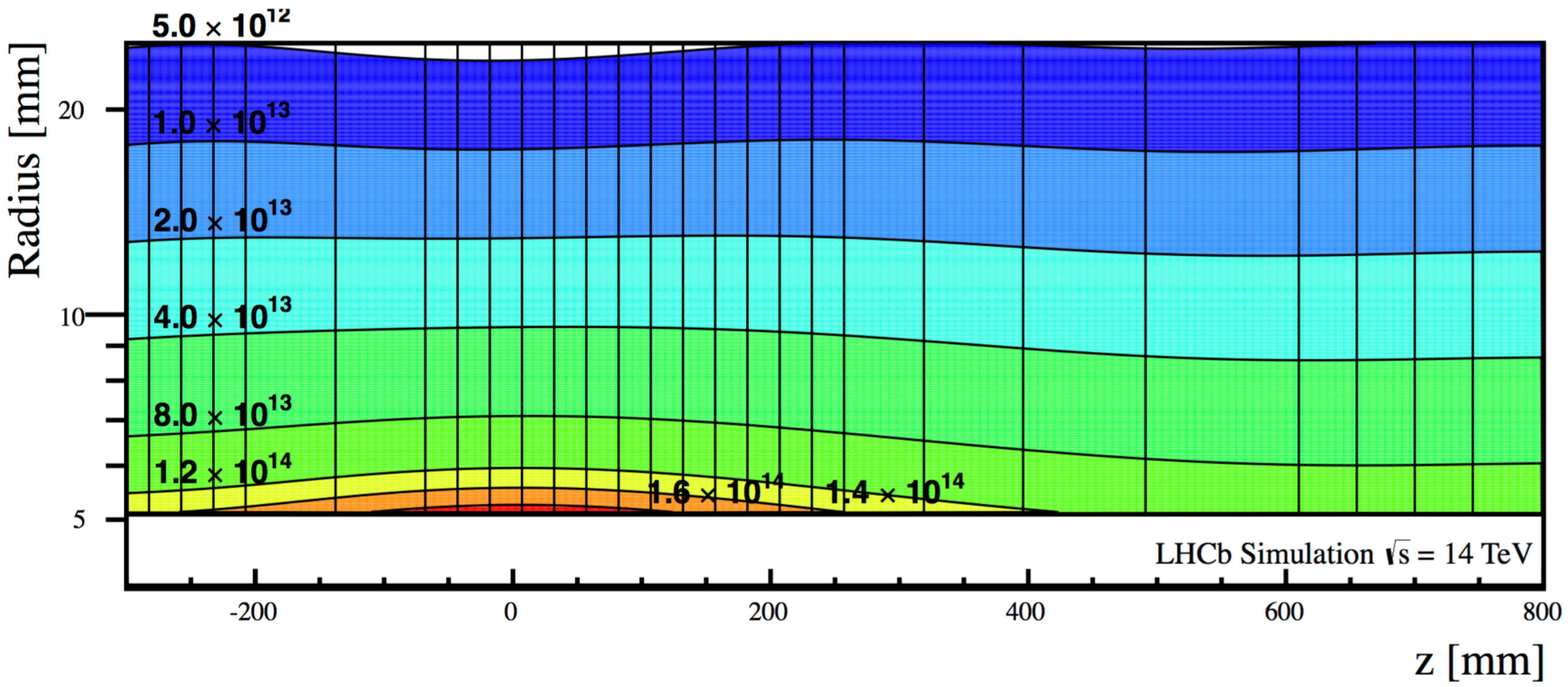
Expected fluence in the most irradiated regions up to 1.5×10^{14} 1MeV n_{eq}/cm^2 per fb^{-1}

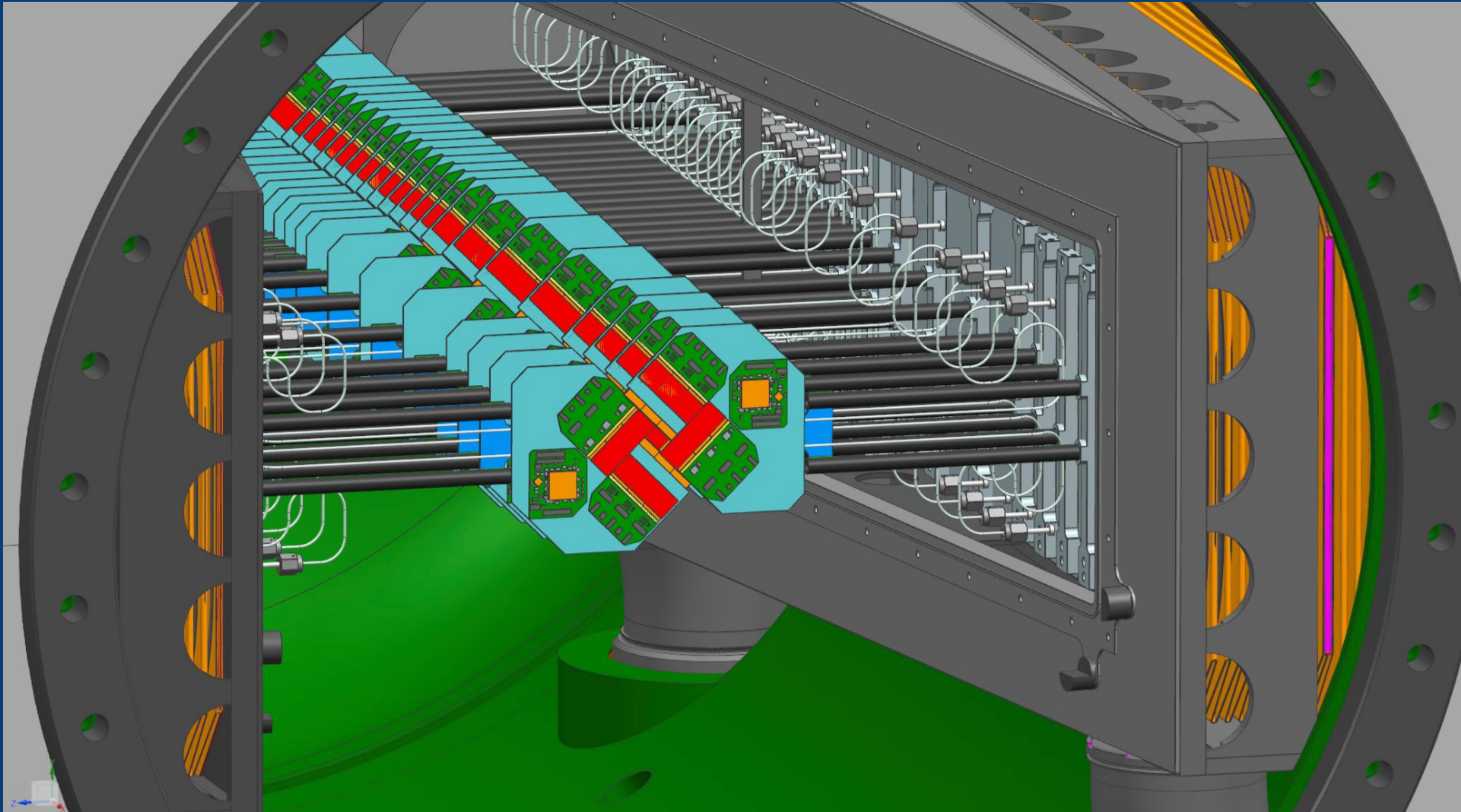
Radiation flux follows $r^{-2.3}$ shape.

Proximity to interaction region: 5.1mm

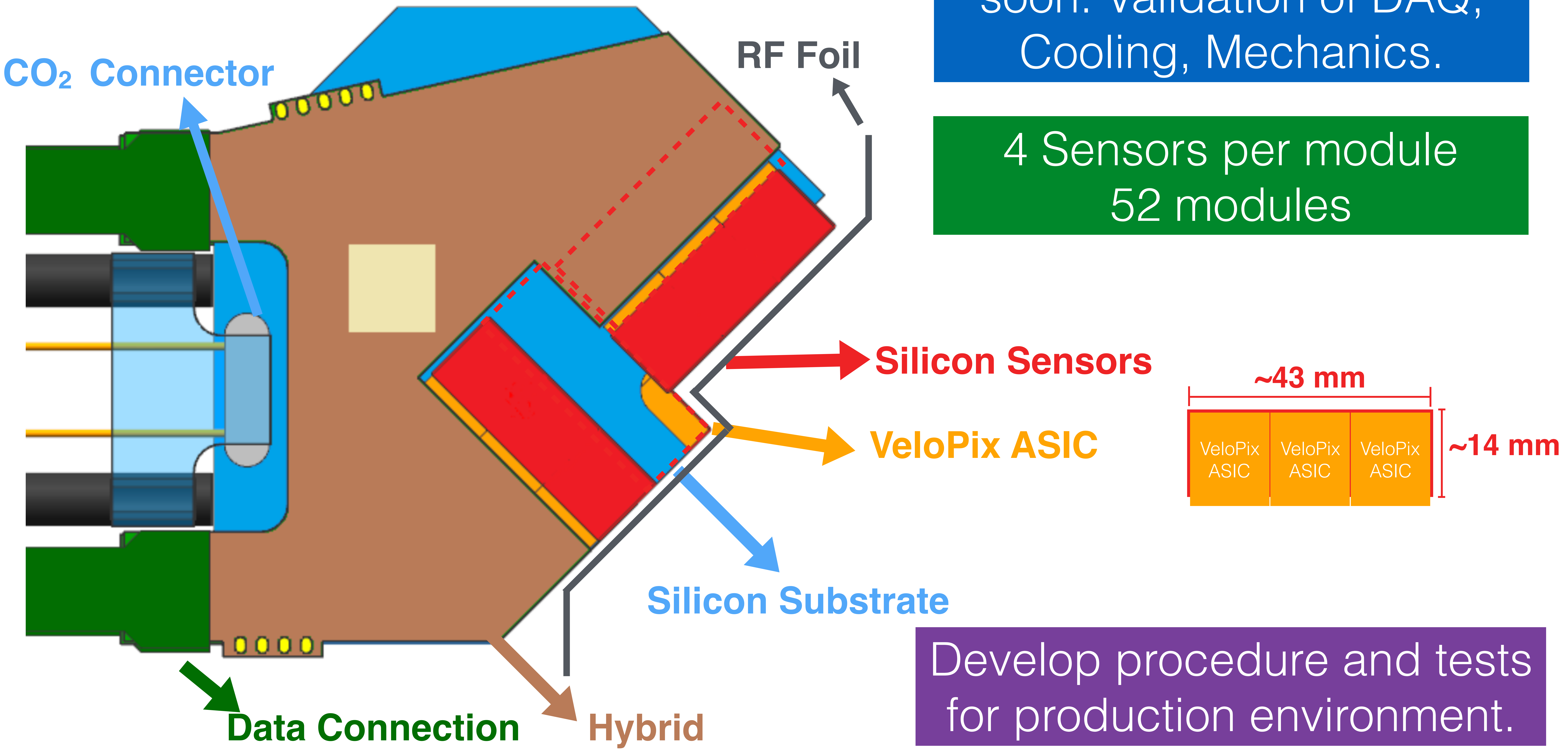
Total Integrated Luminosity: 50fb^{-1} !







VELO Upgrade Module

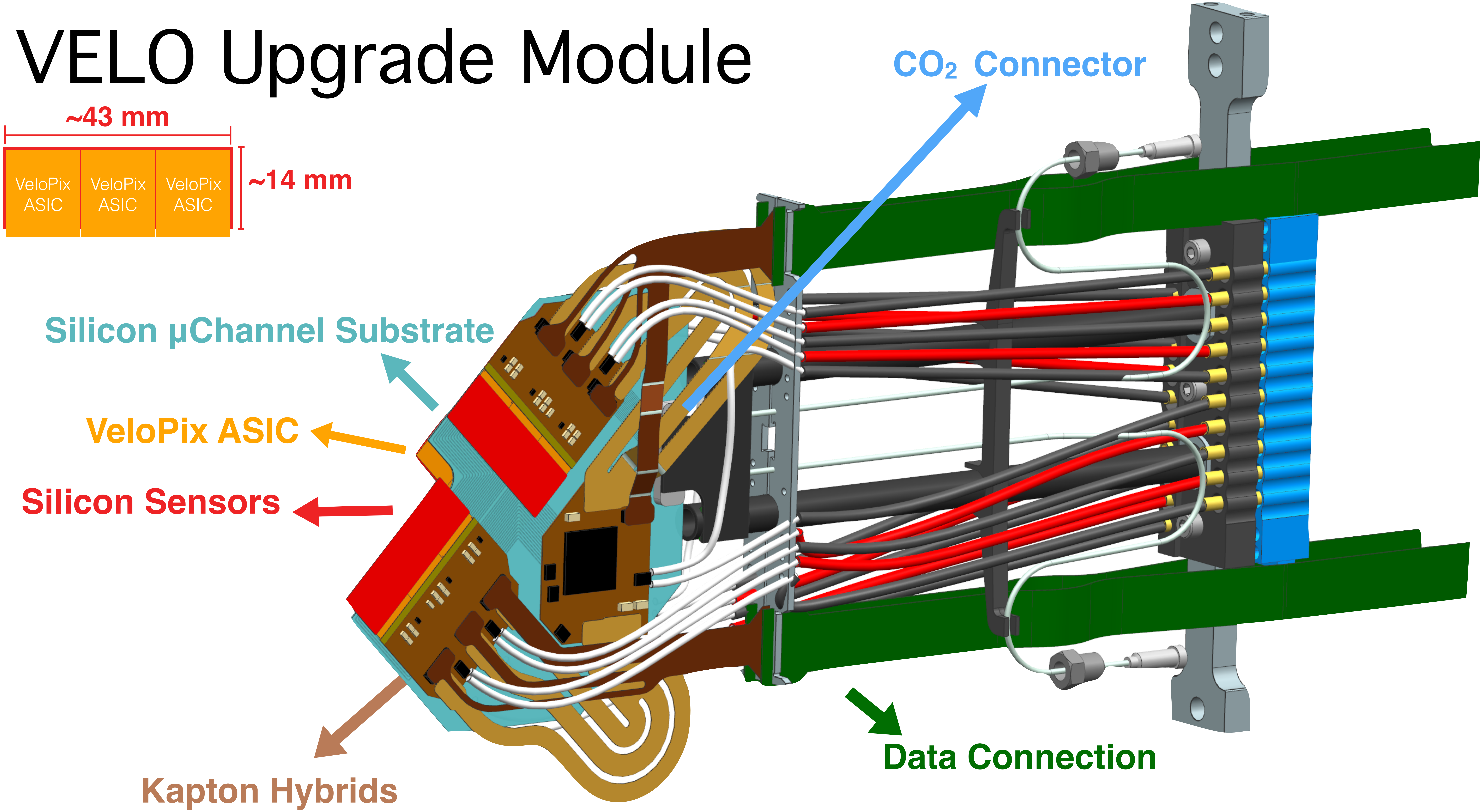


Module PRR to happen soon. Validation of DAQ, Cooling, Mechanics.

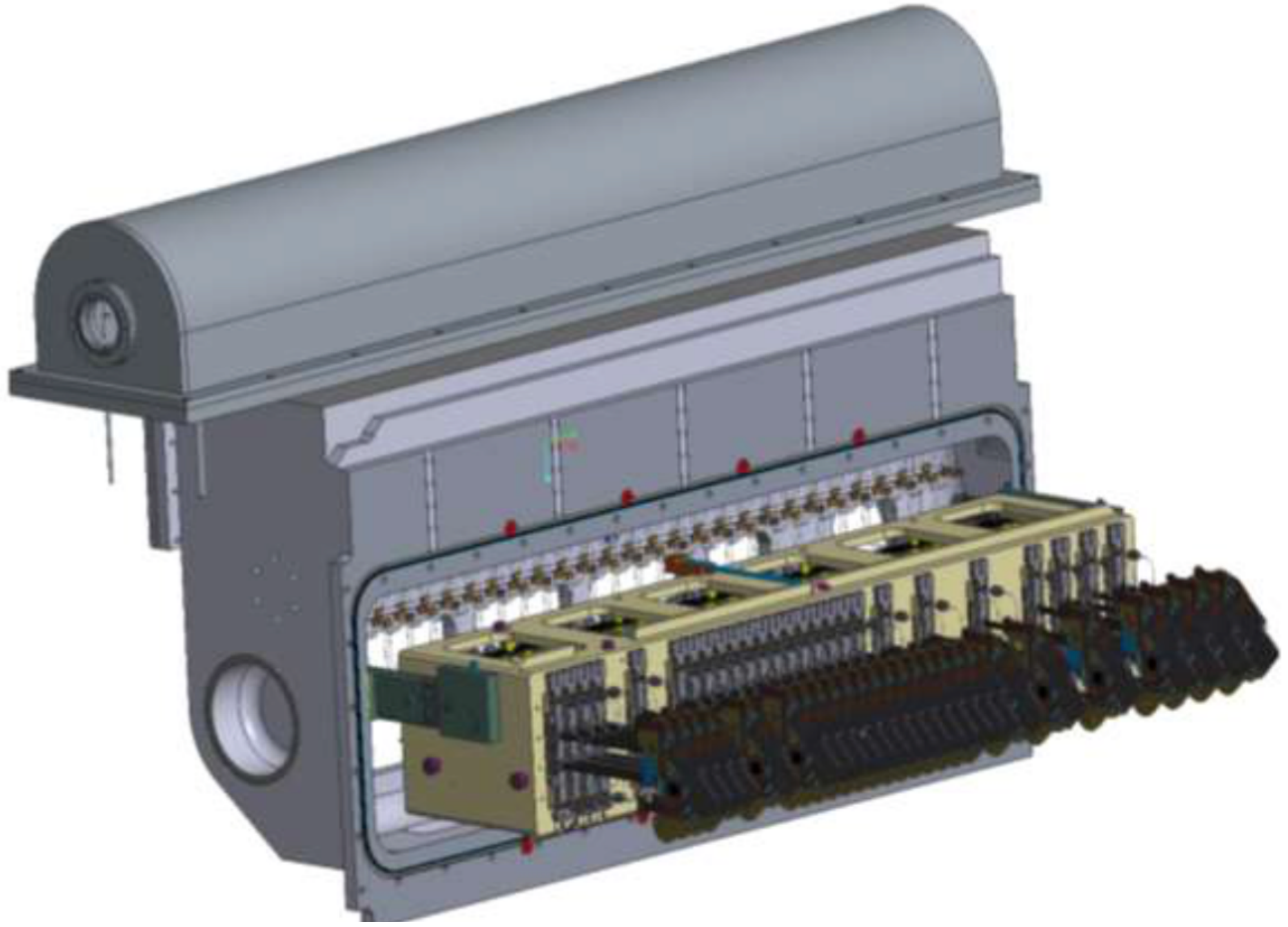
4 Sensors per module
52 modules

Develop procedure and tests for production environment.

VELO Upgrade Module

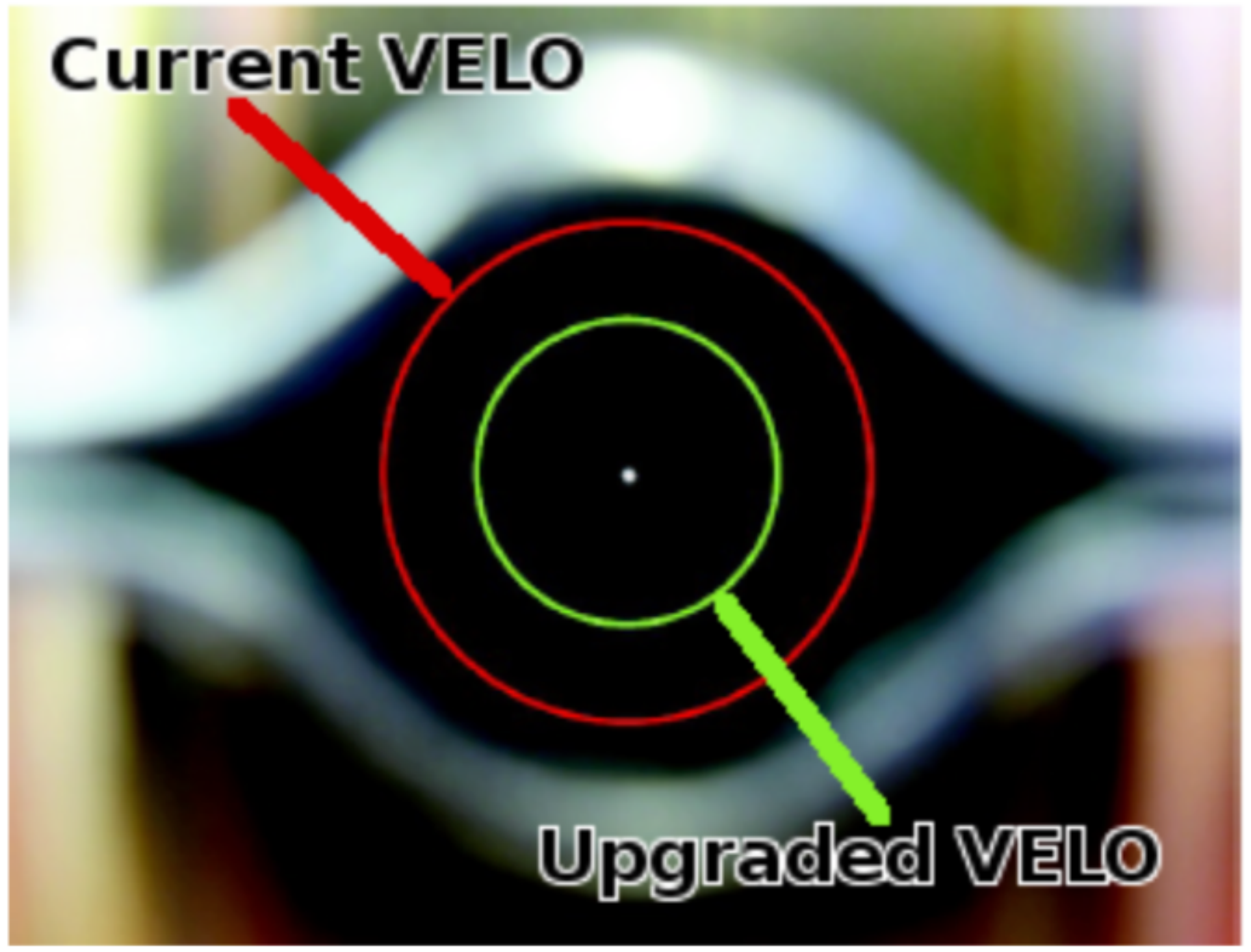


Mechanics



VELO Hood in production.

RF Foil separates the LHC beam from the VELO secondary Vacuum.

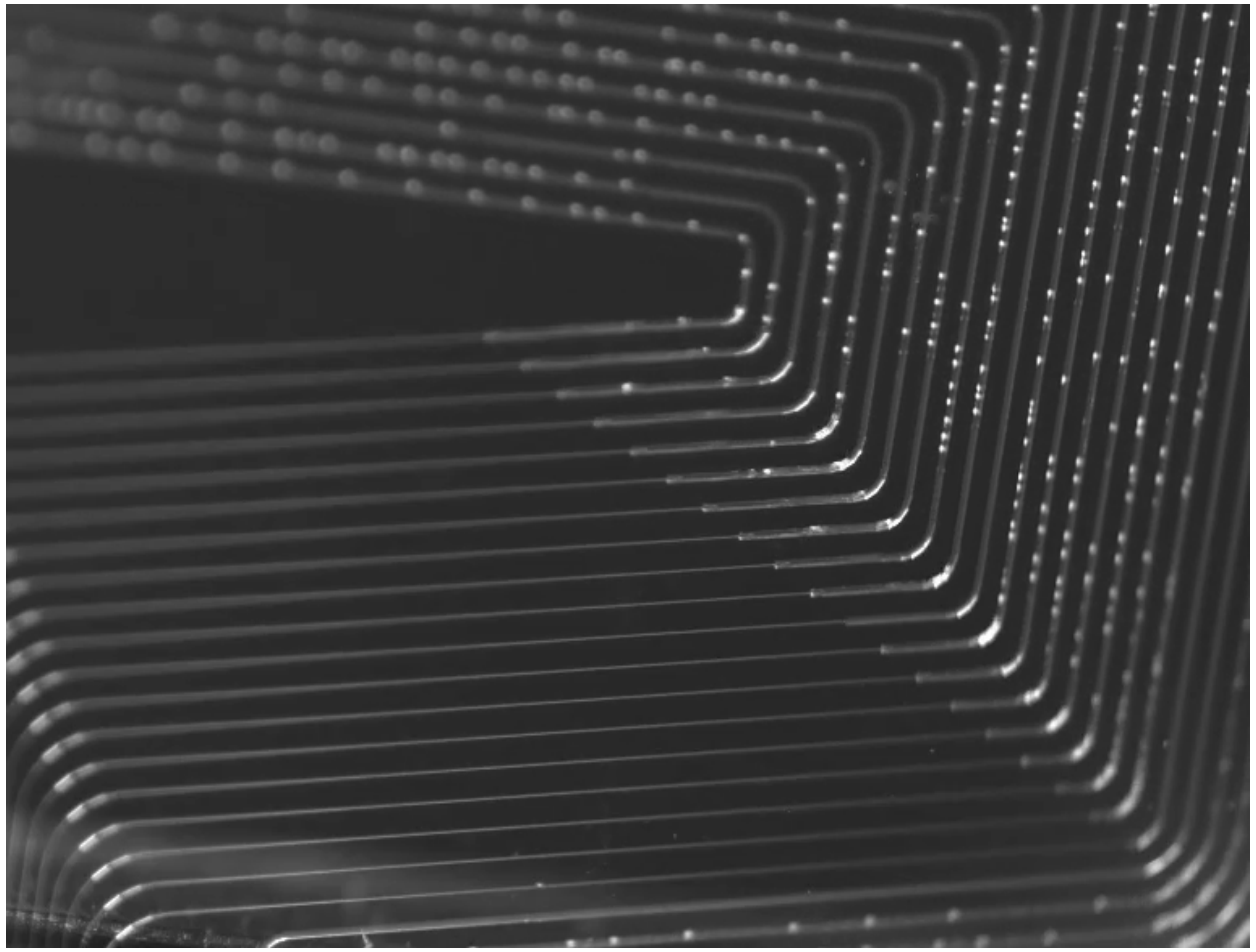


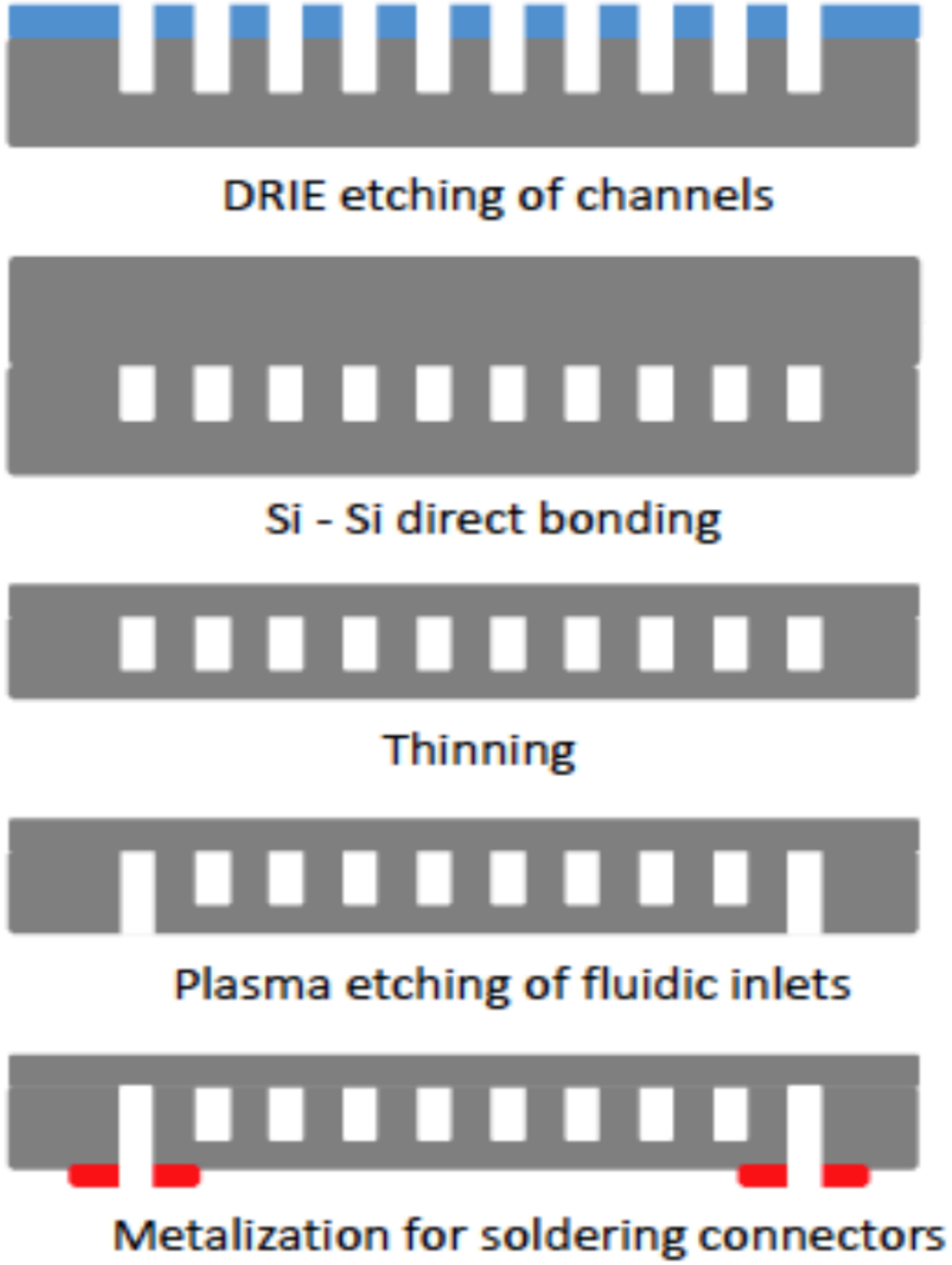
New RF Foil, thinned down to 250um.

μ-Channel Cooling

More details on my Poster!

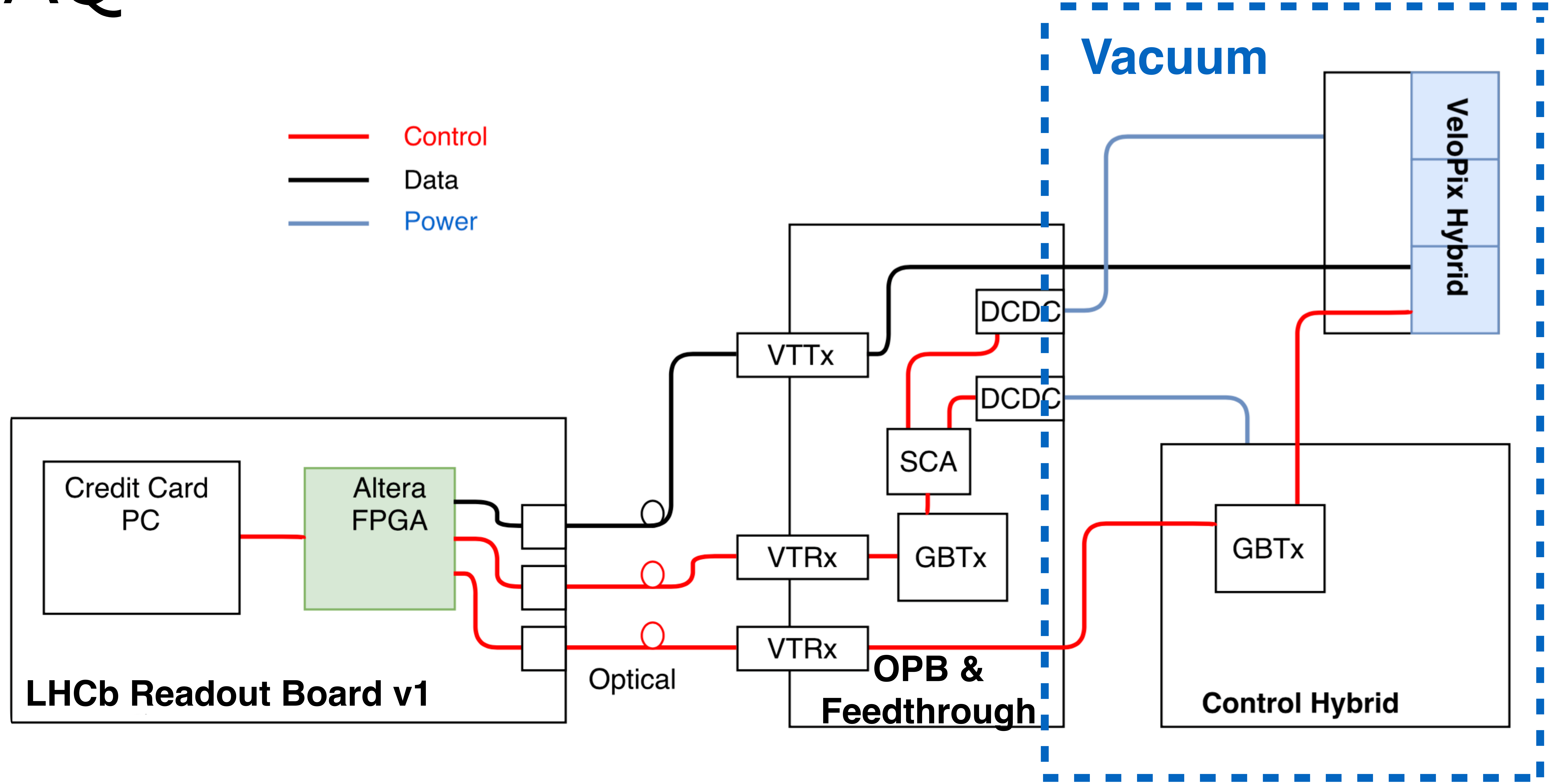
Silicon substrate built with micro channels that will carry CO_2 for evaporative cooling.





System designed to cool a load of up to 30W from each module.

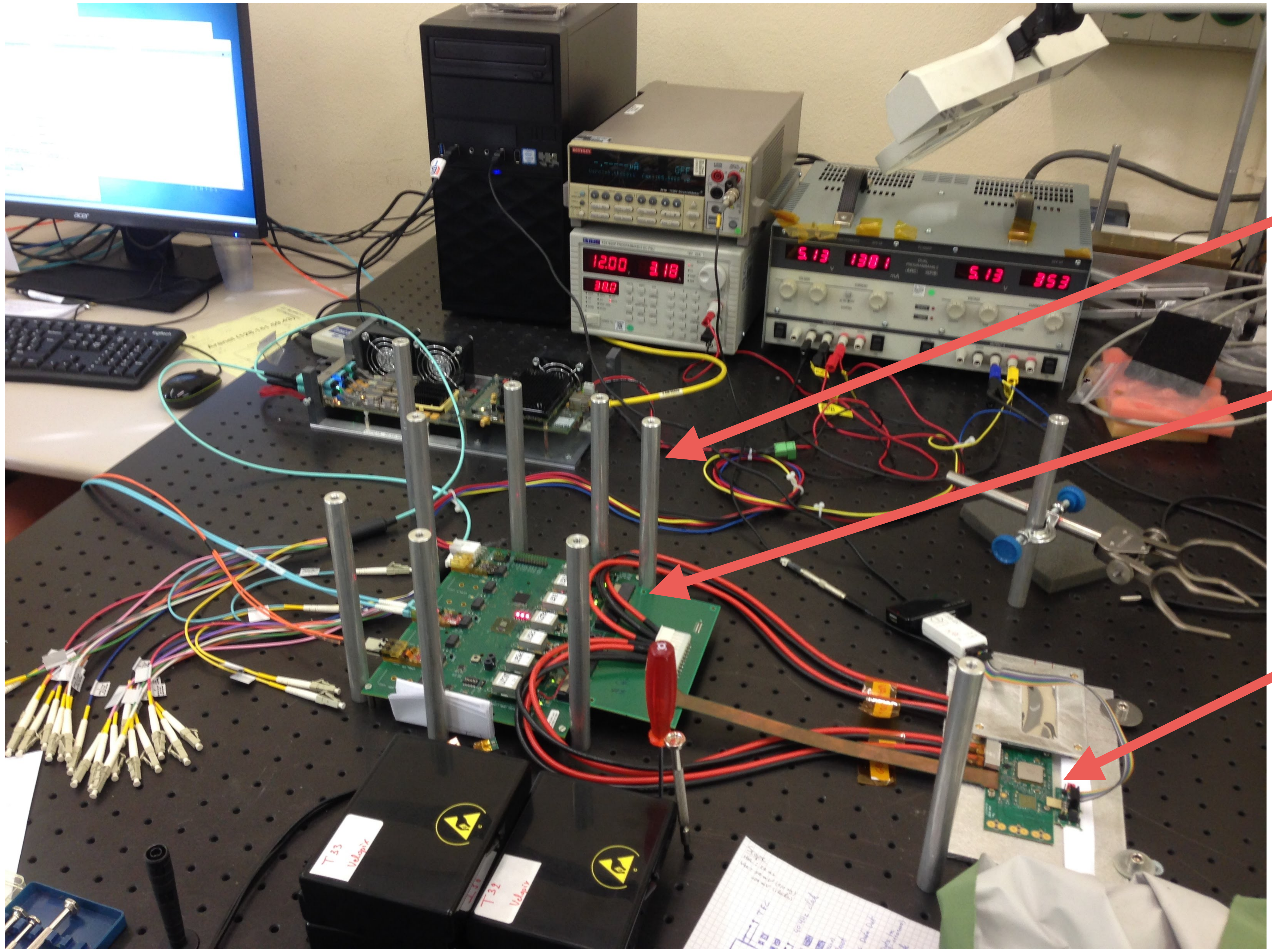
DAQ

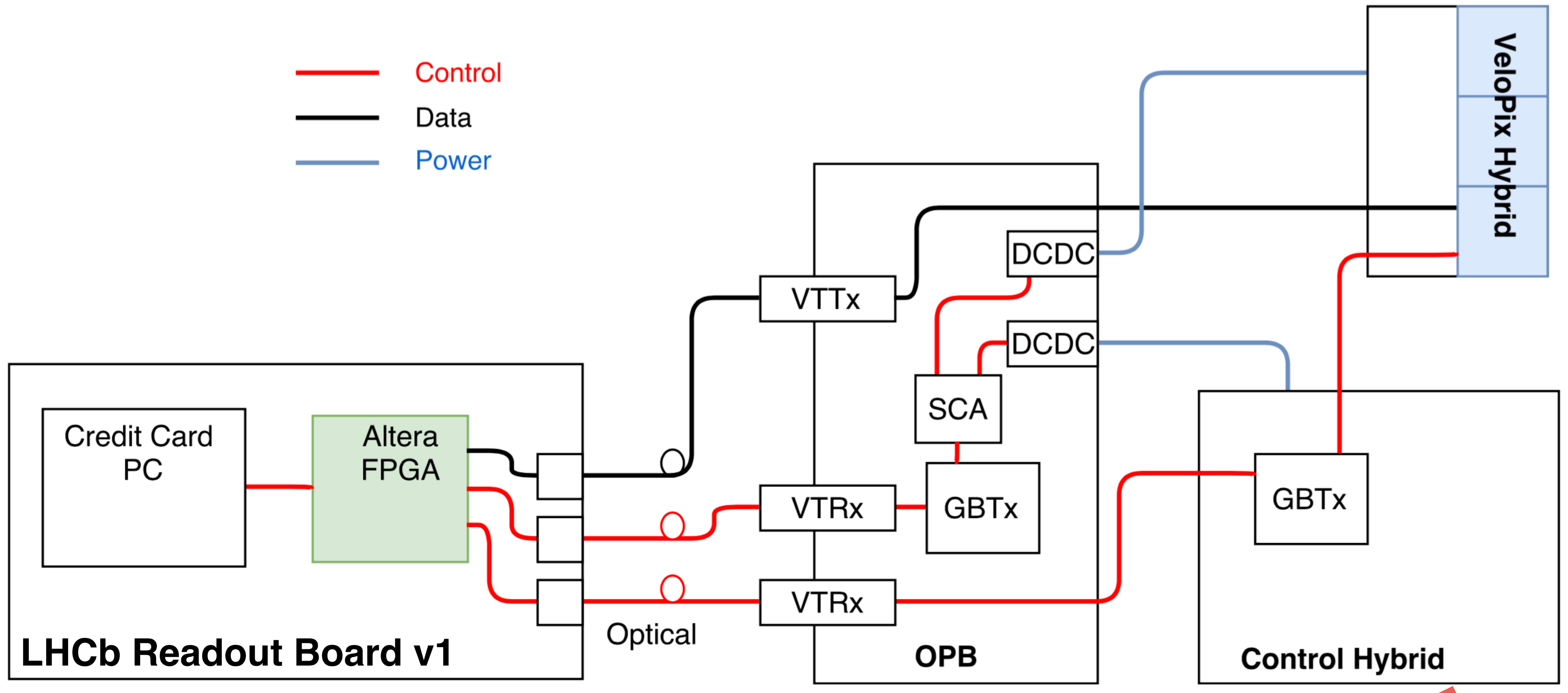


Vacuum
Control
Data
Power
VeloPix Hybrid
DCDC
DCDC
VTTx
SCA
Credit Card PC
Altera FPGA
VTRx
GBTx
VTRx
GBTx
Optical
OPB & Feedthrough
Control Hybrid
LHCb Readout Board v1

DAQ

VeloPix hybrids being tested with LHCb Upgrade Readout boards.





Firmware integrated pre-existing software, most necessary procedures already in place.

VeloPix

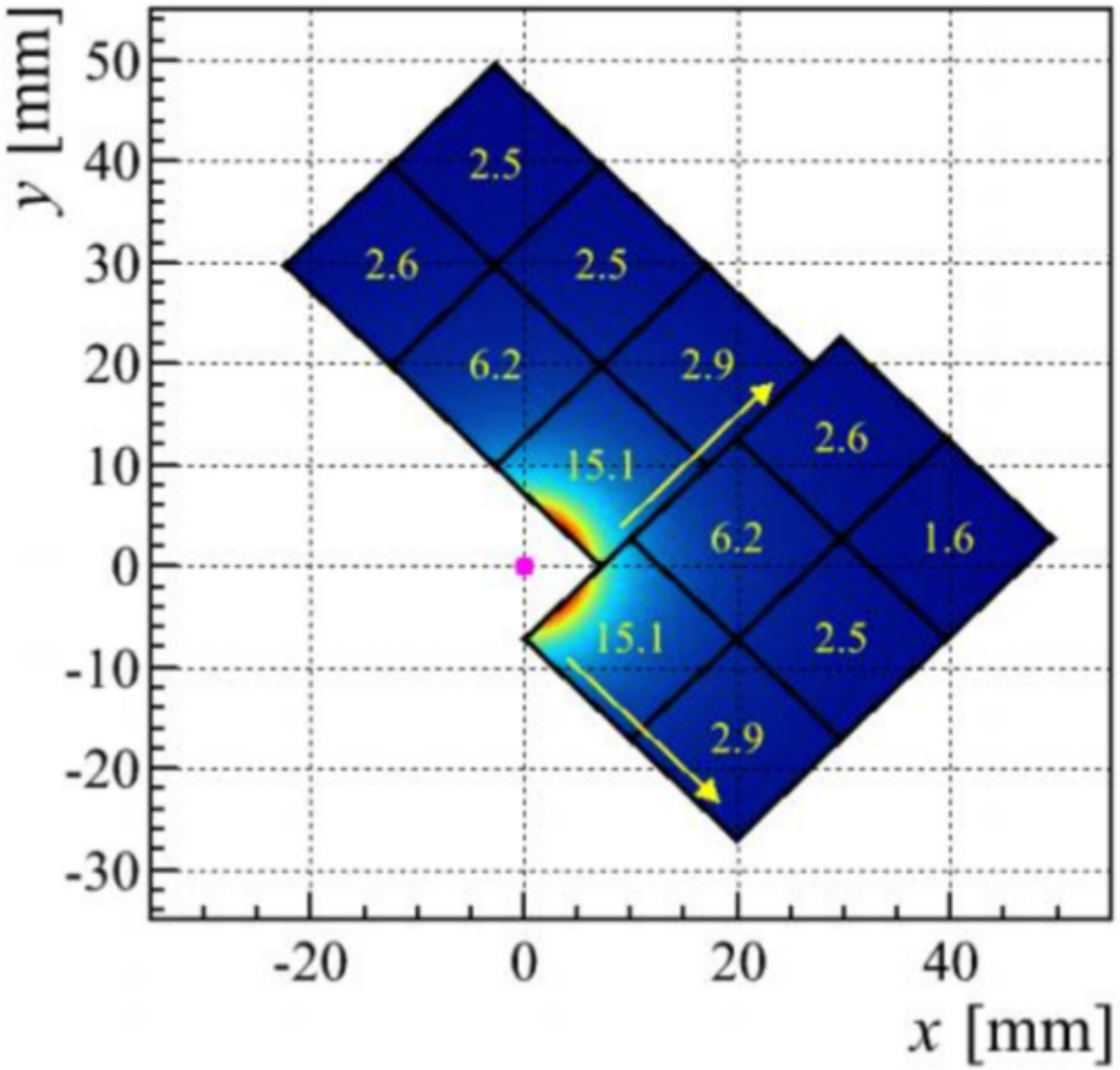
Data driven, binary readout, 25 ns timestamping.

Design based on the Timepix3 ASIC.

65k pixels/ASIC
55µm x 55µm pixels
Triggerless readout

Optimised for high speed readout.

Peak Rate: 800 Mhits/s/ASIC
Max ASIC Bandwidth: 20.48 Gb/s

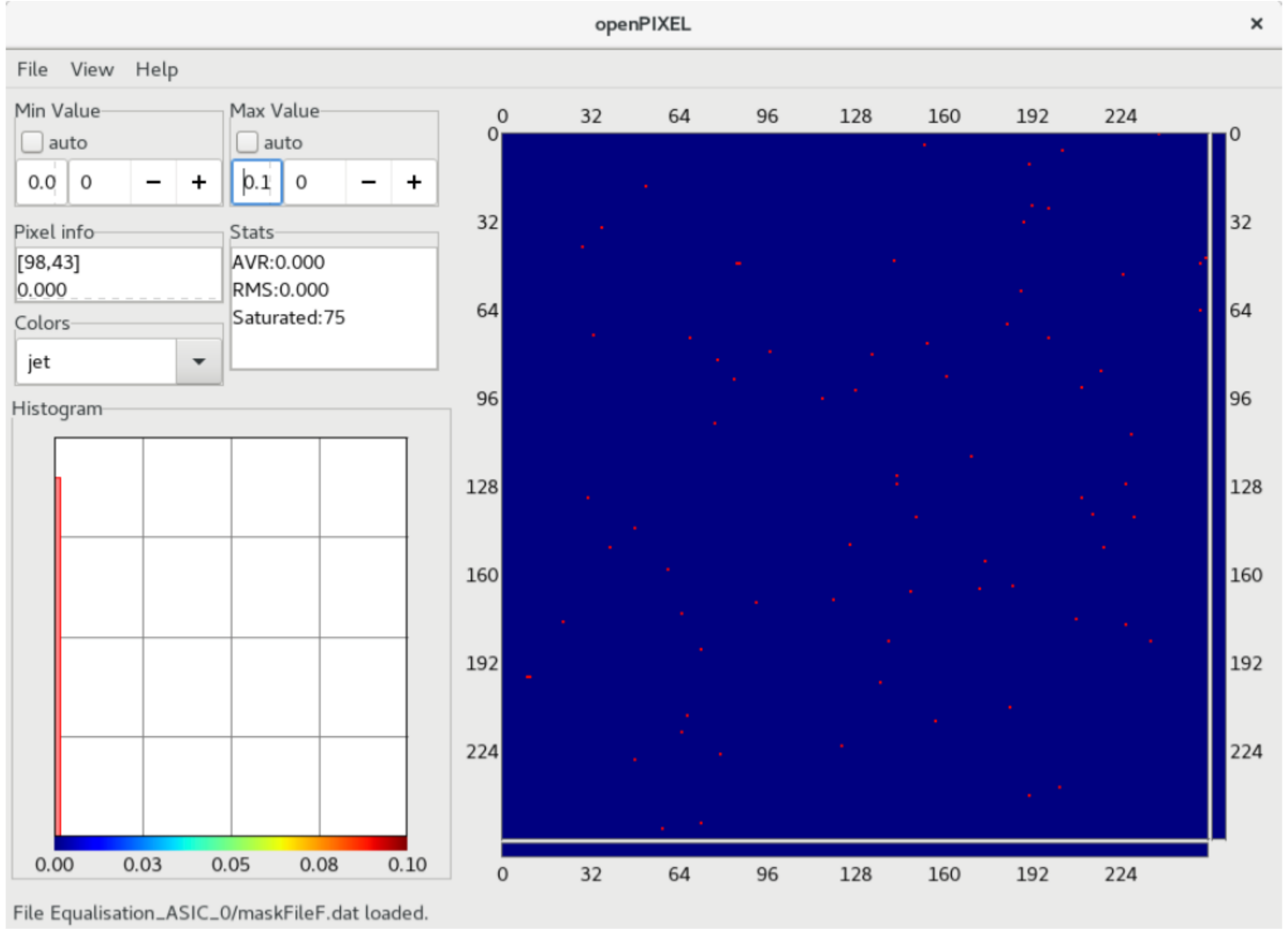


Data rate [Gbit/s] for hottest module.

SEU Tolerance built in. Radiation Hard up to 400 MRad

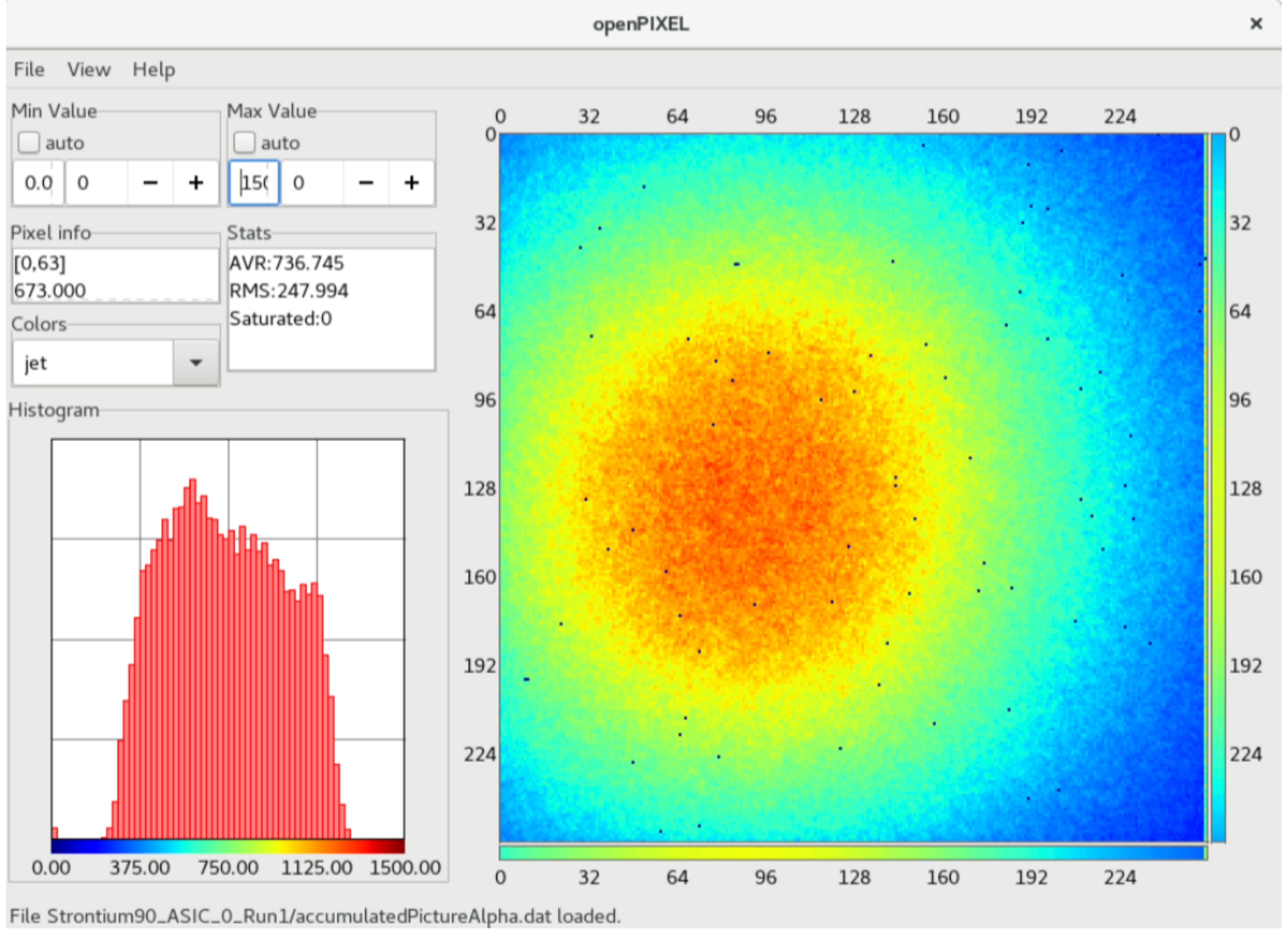
UNIVERSITY OF LIVERPOOL

VeloPix Hybrid



Equalisation provides uniform ASIC operation.

Radioactive source measurements allow double check of single pixel response.

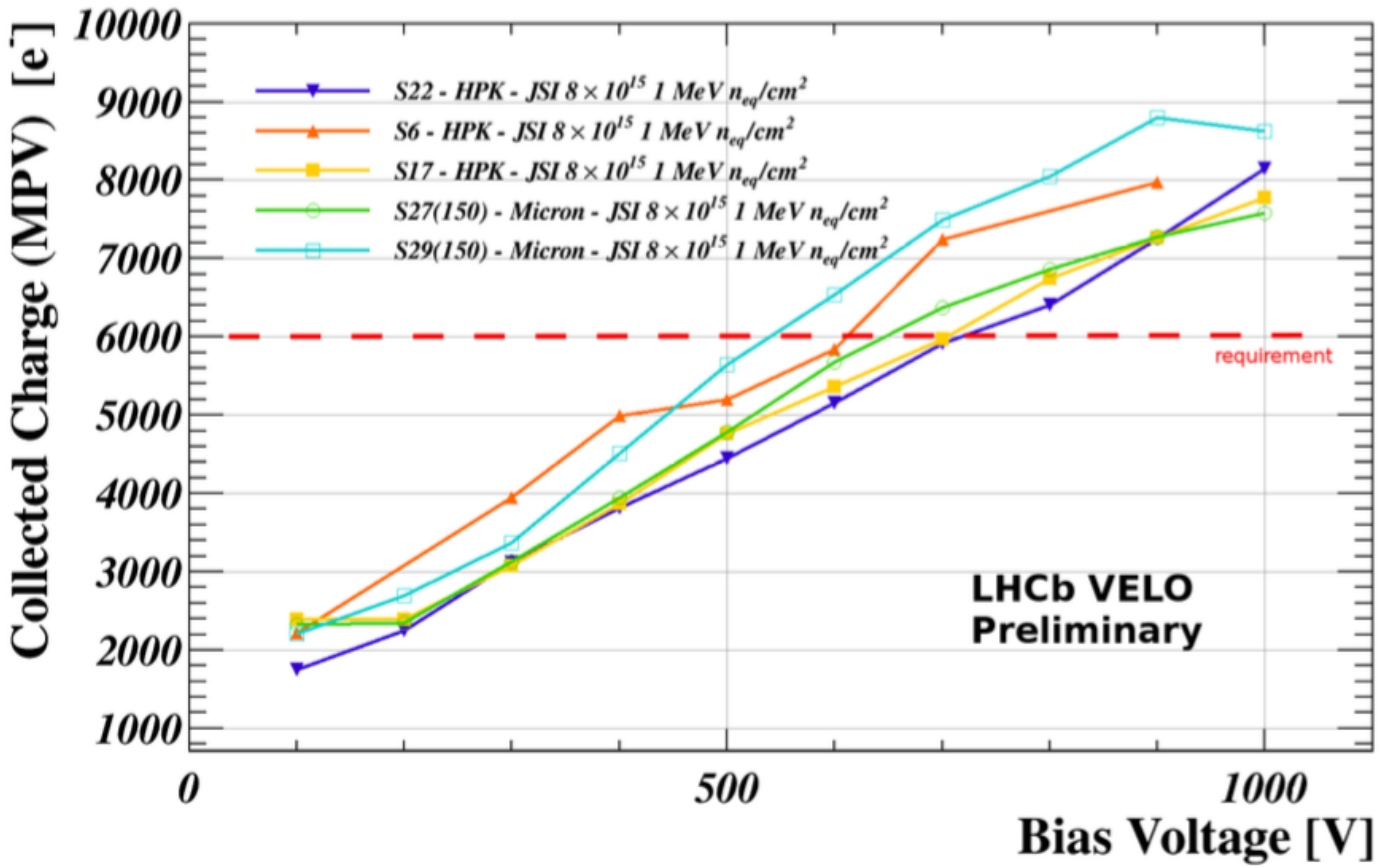


Charge Collection

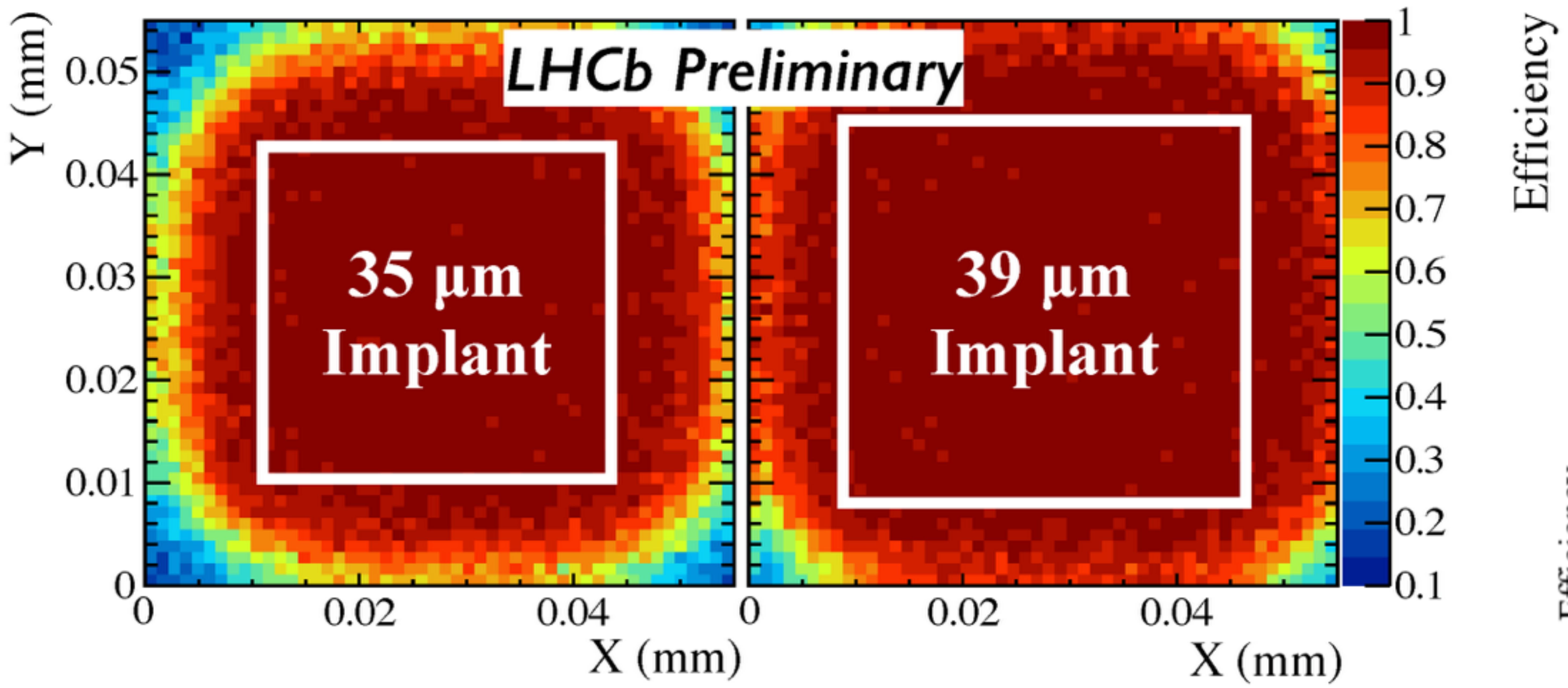
Max Operational Bias Voltage: 1000V

Minimum collected charge per MIP: 6000e$^-$

The sensors must be able to operate under these conditions up to 8×10^{15} 1MeV $n_{eq}cm^{-2}$



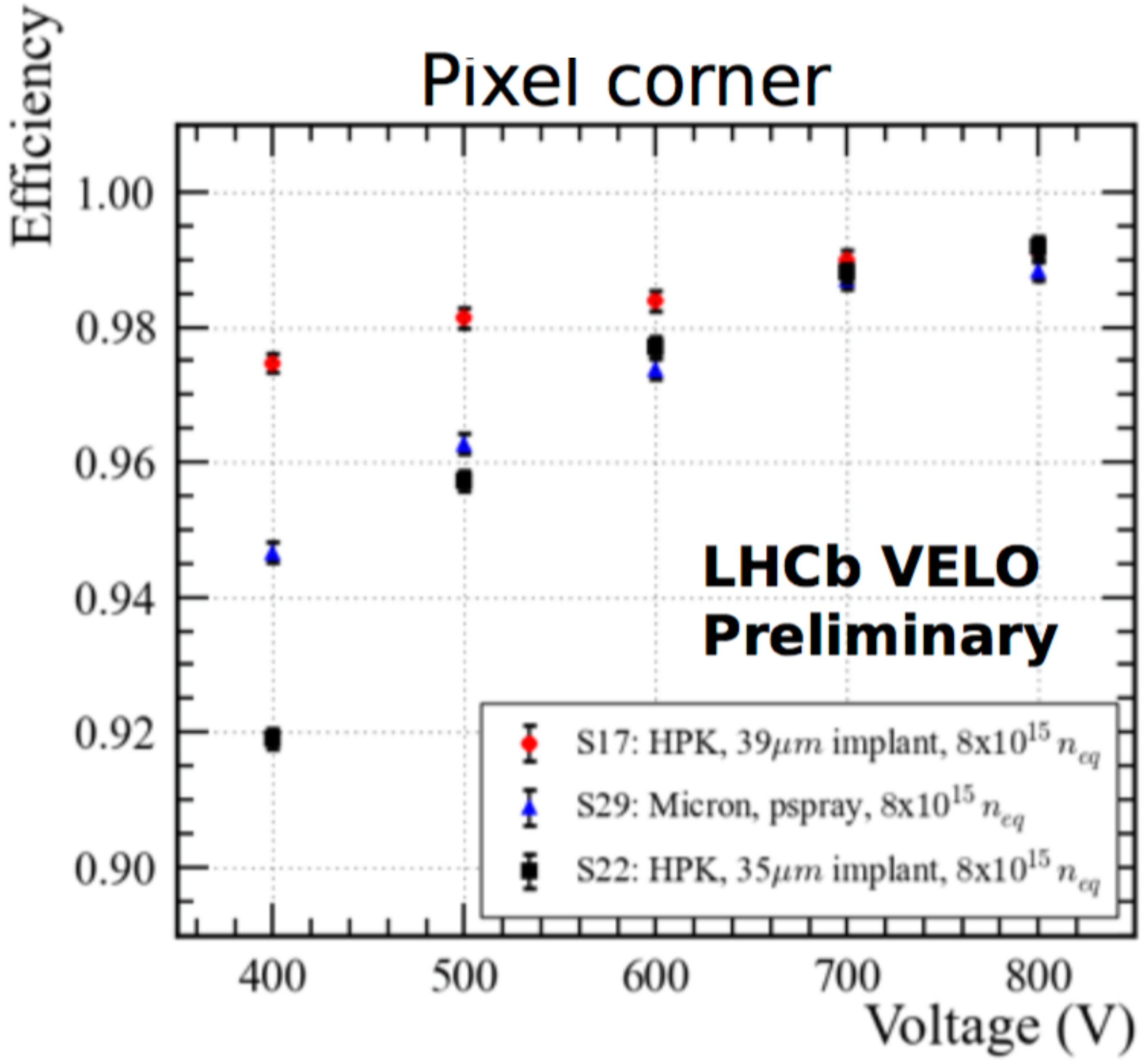
Efficiency



Efficiency studied using Timepix3 Telescope in SPS.

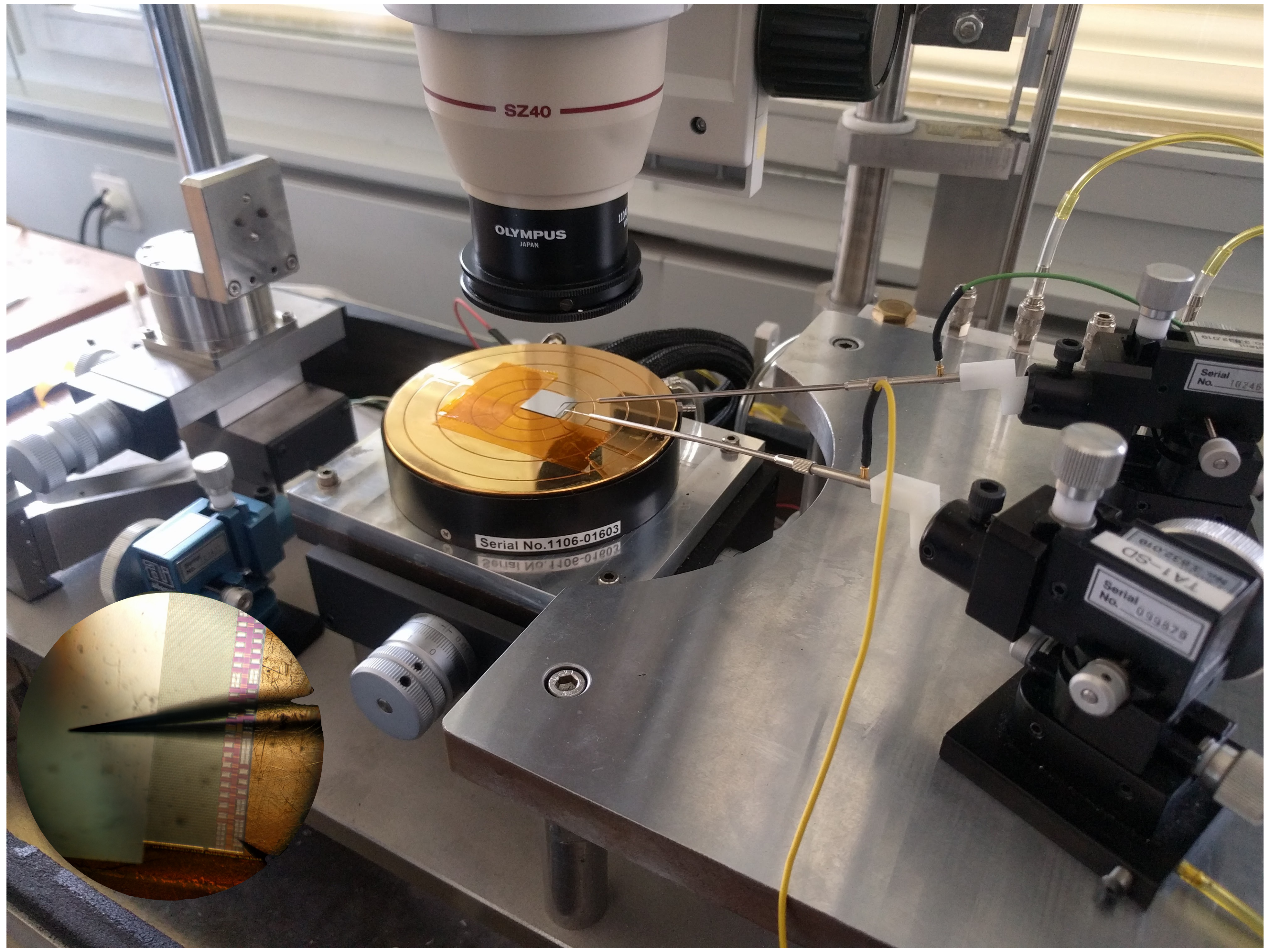
Using 39 µm p-type implants.

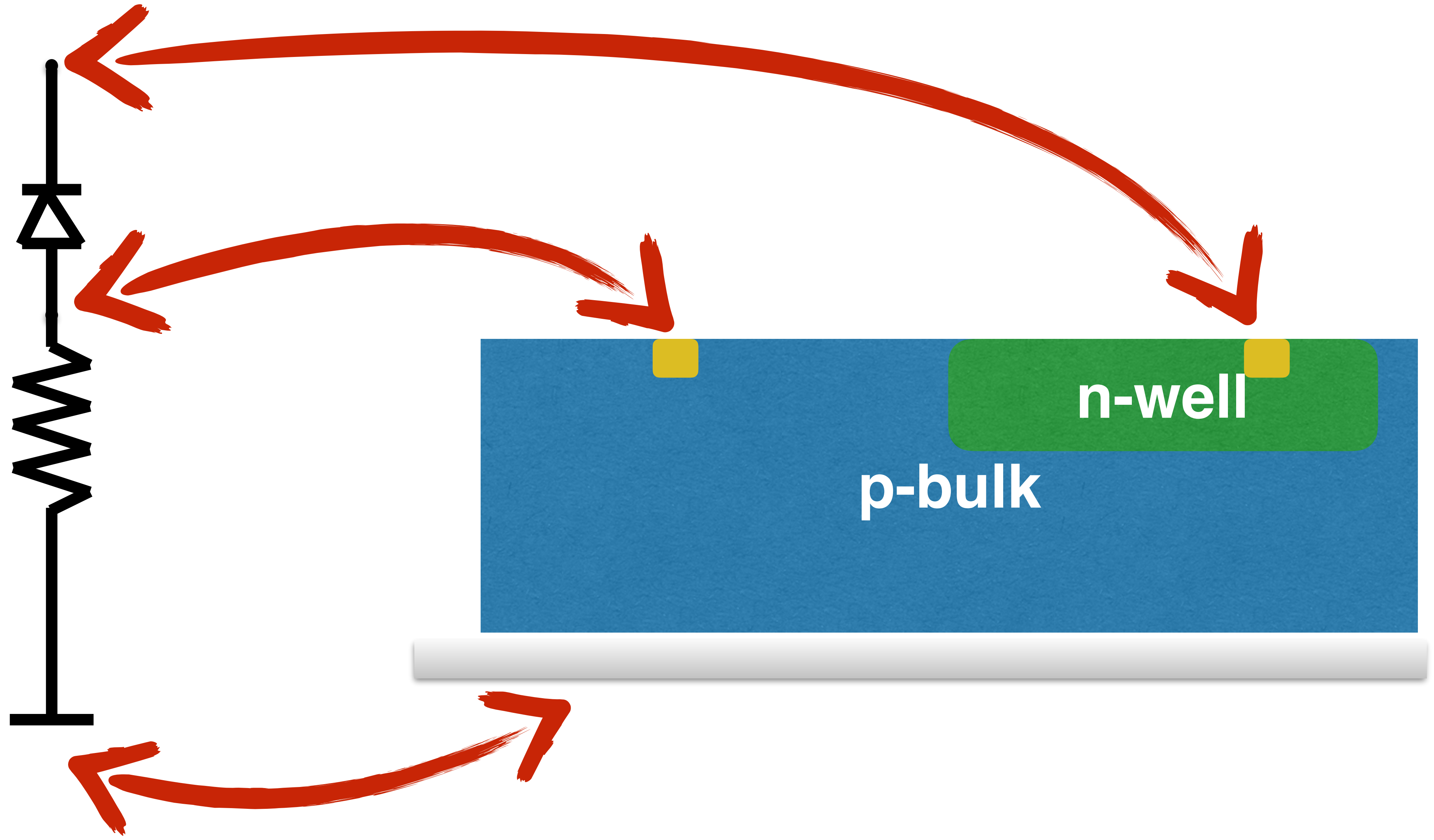
Pixel corner efficiency >99% @ 1000V after VELO lifetime fluence.

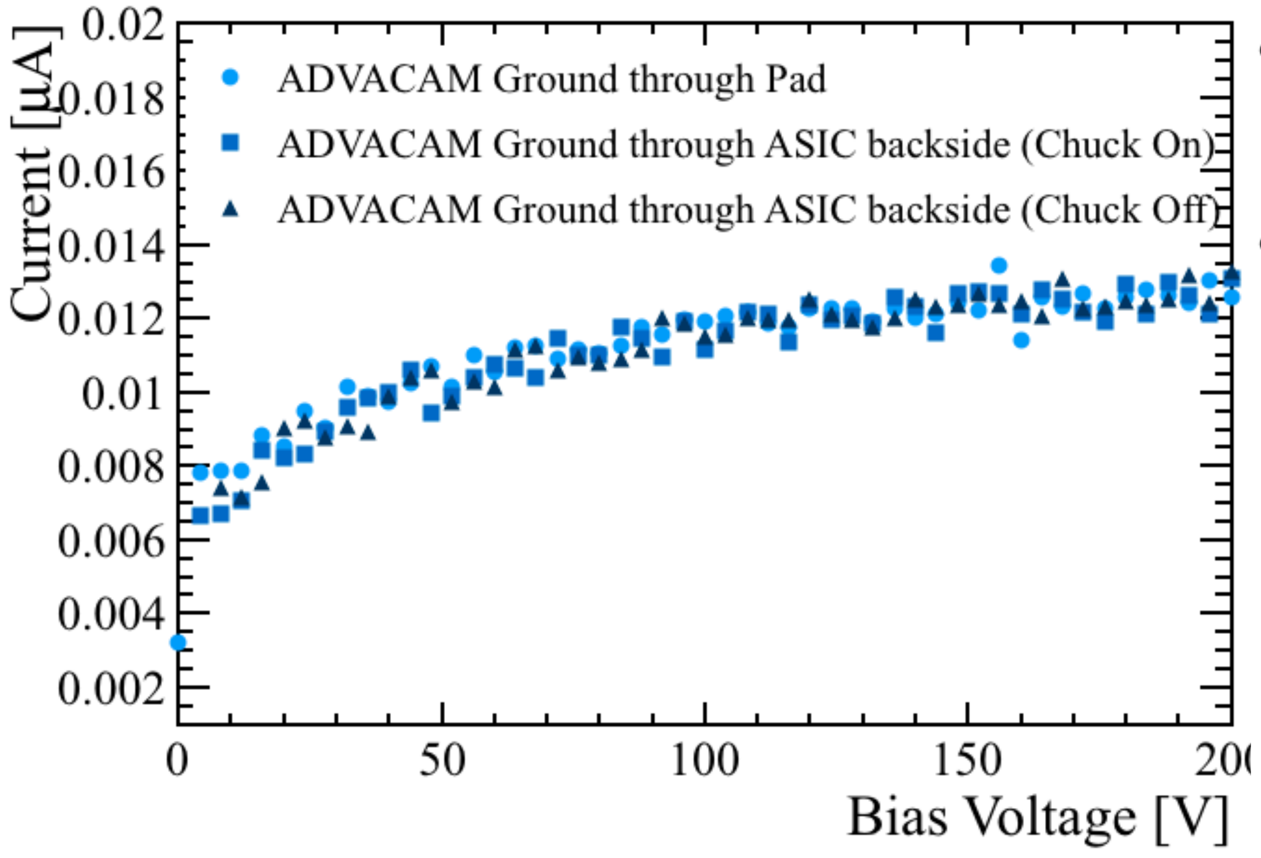


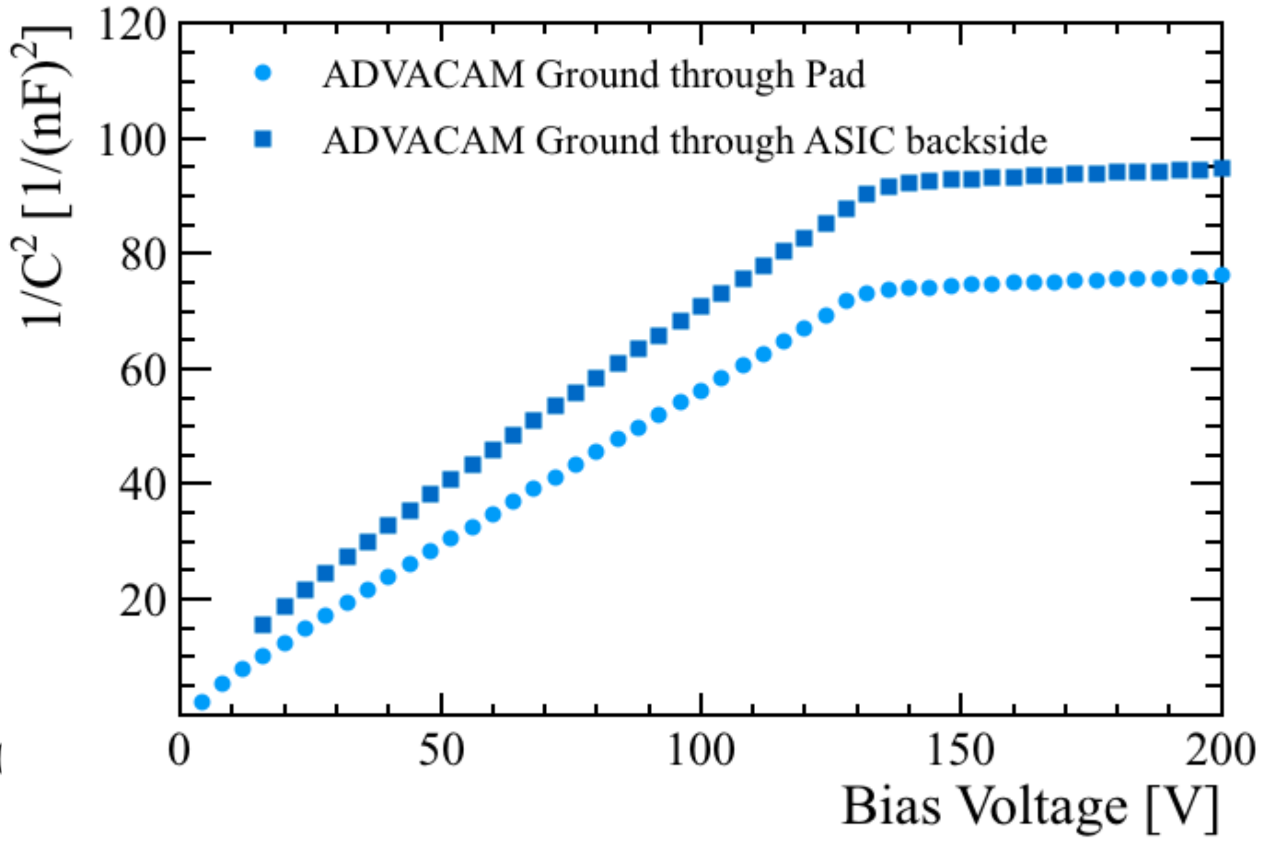
Perpendicular tracks

What about Sensor HV Tolerance?







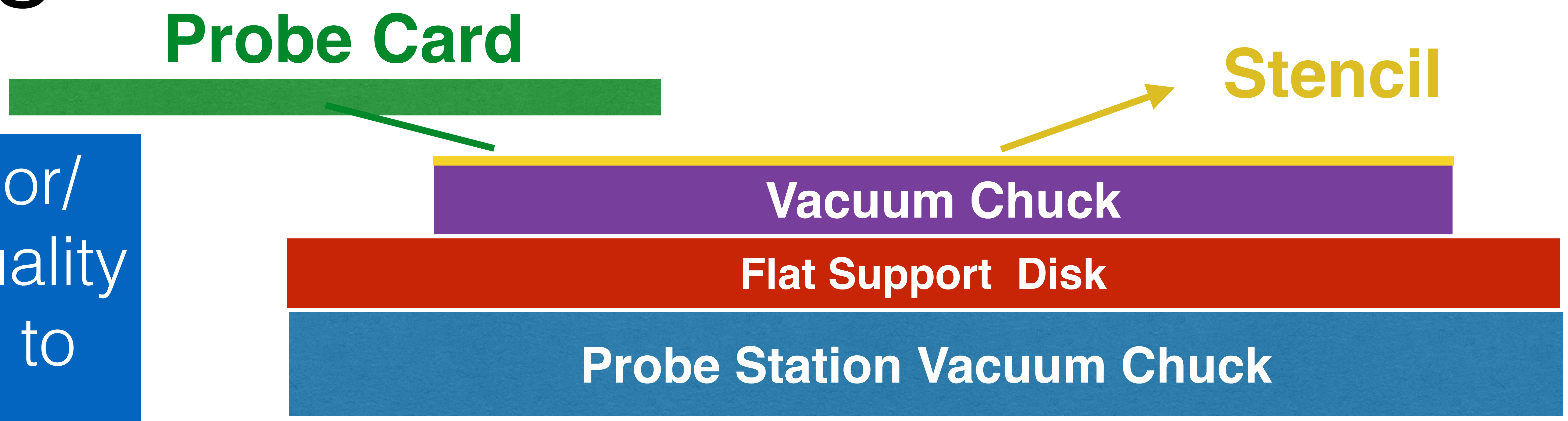


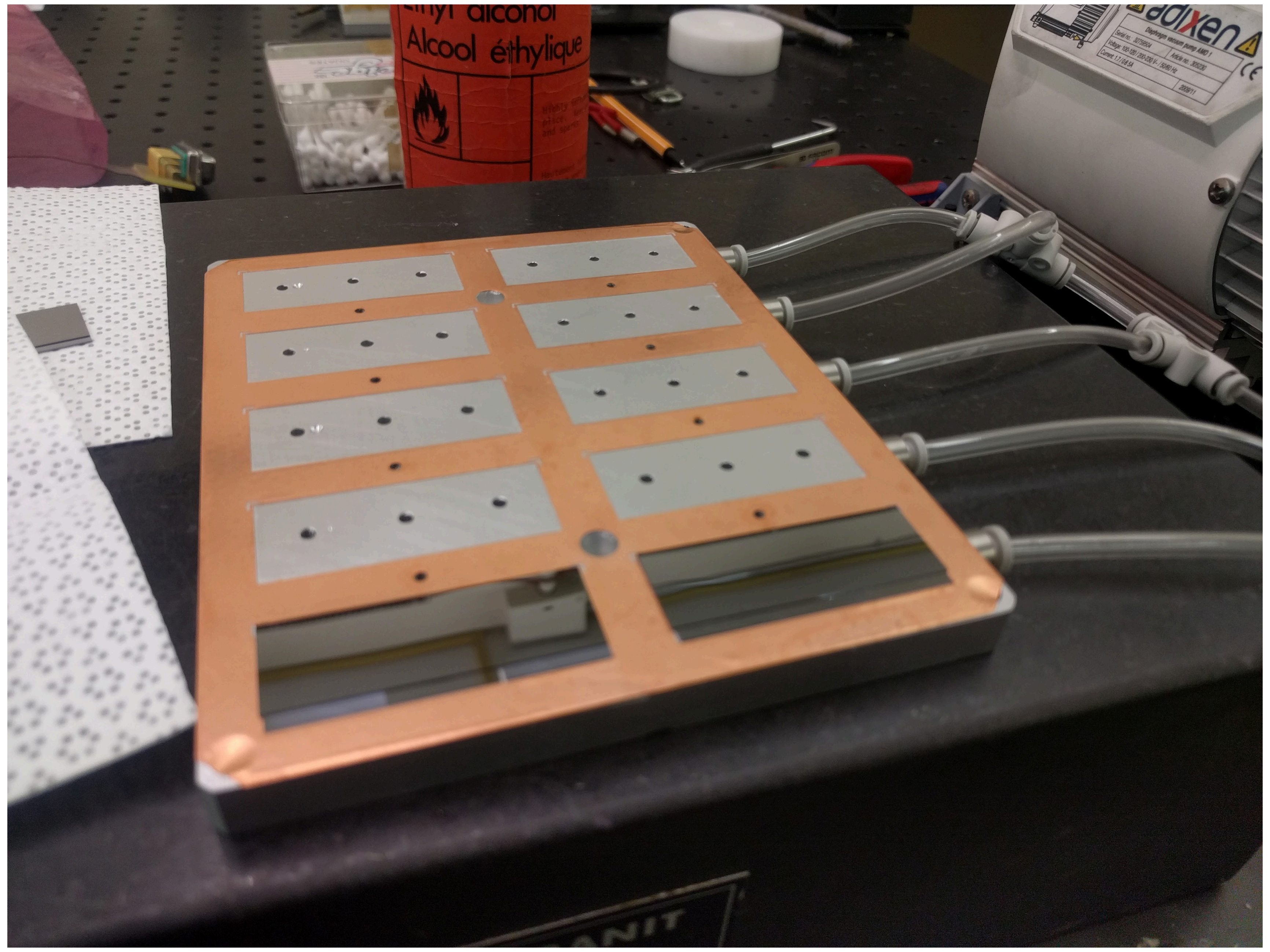
Maybe we can ground the sensor through the ASIC!

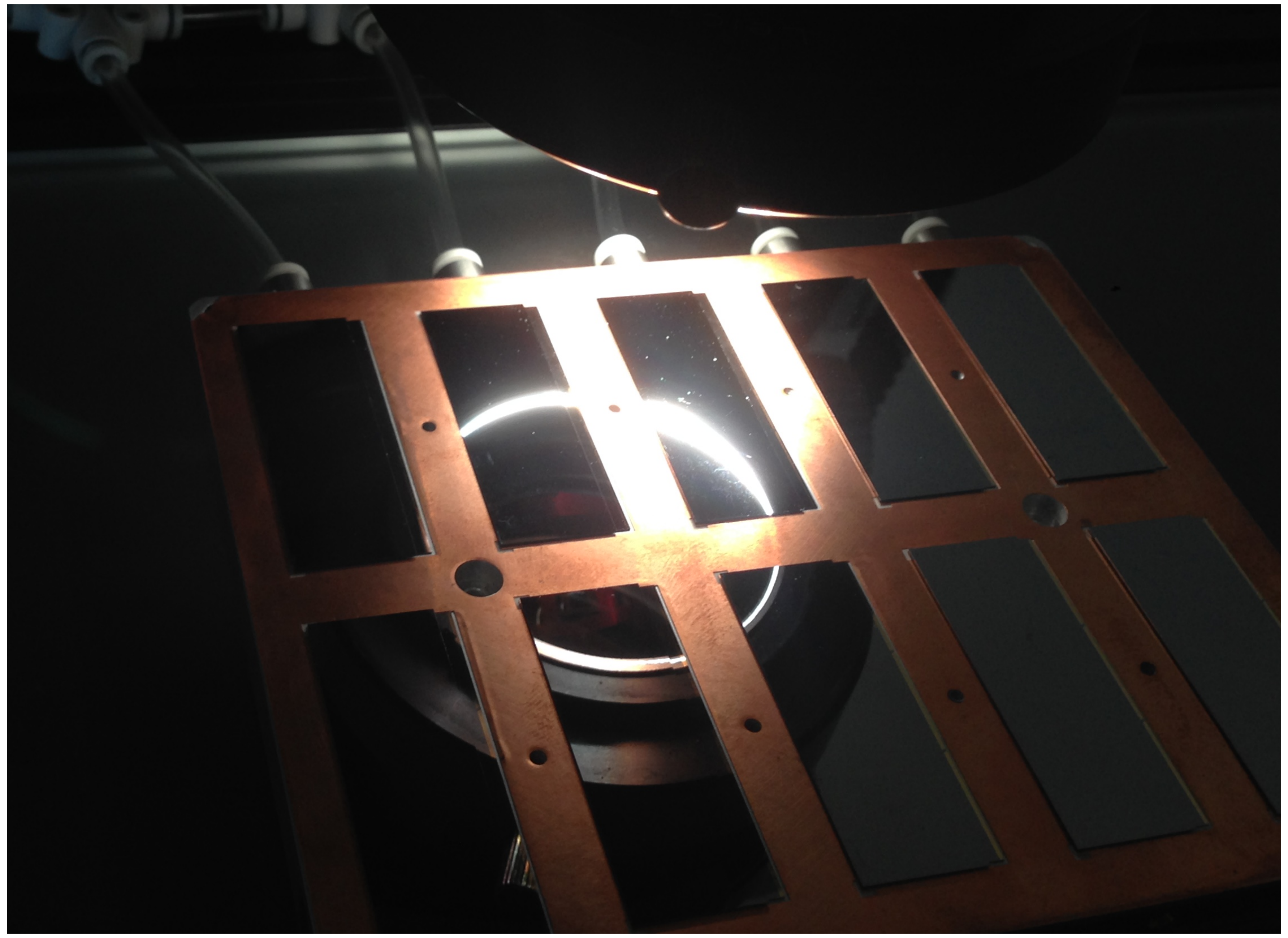
Thanks to Michael Moll, for the use of probe setup.

Probe Card Jig

How to test each sensor/ ASIC for bump bond quality before mounting them to modules ?

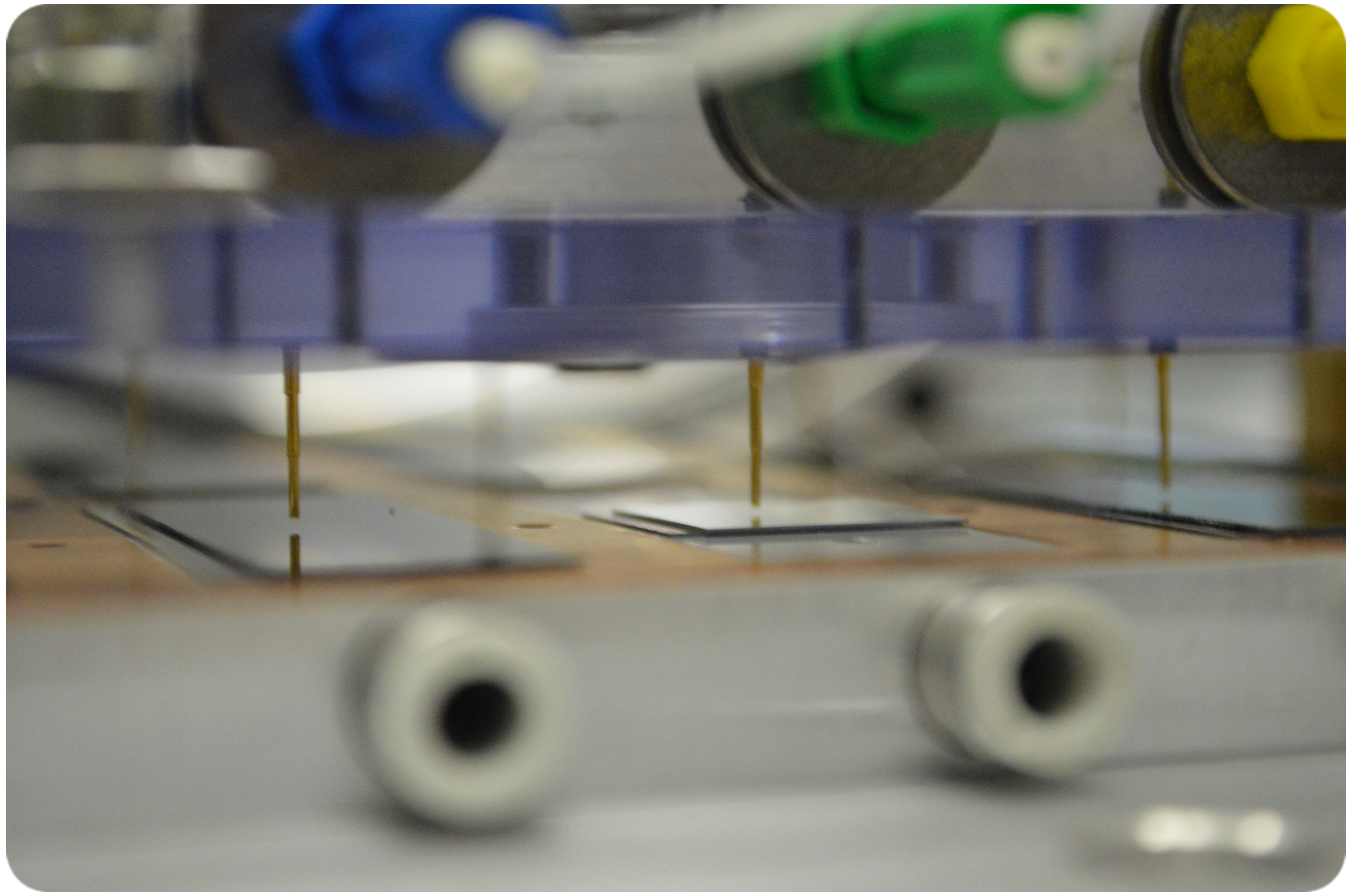


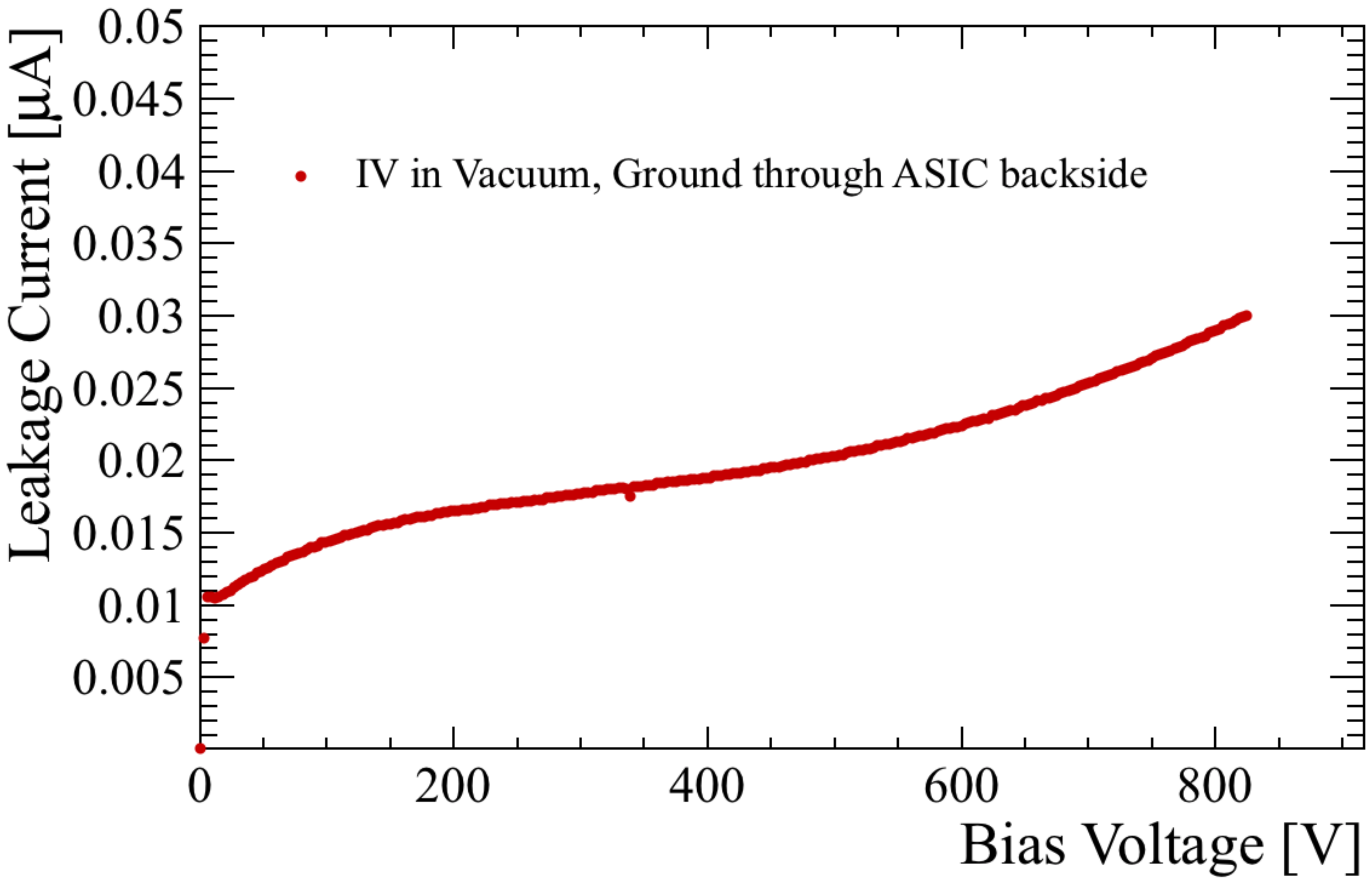




40µm precision

Bell Jar Jig





Spring loaded probe needles keep small pressure on sensors.

Dowels stop needles before end of spring compression.

Summary

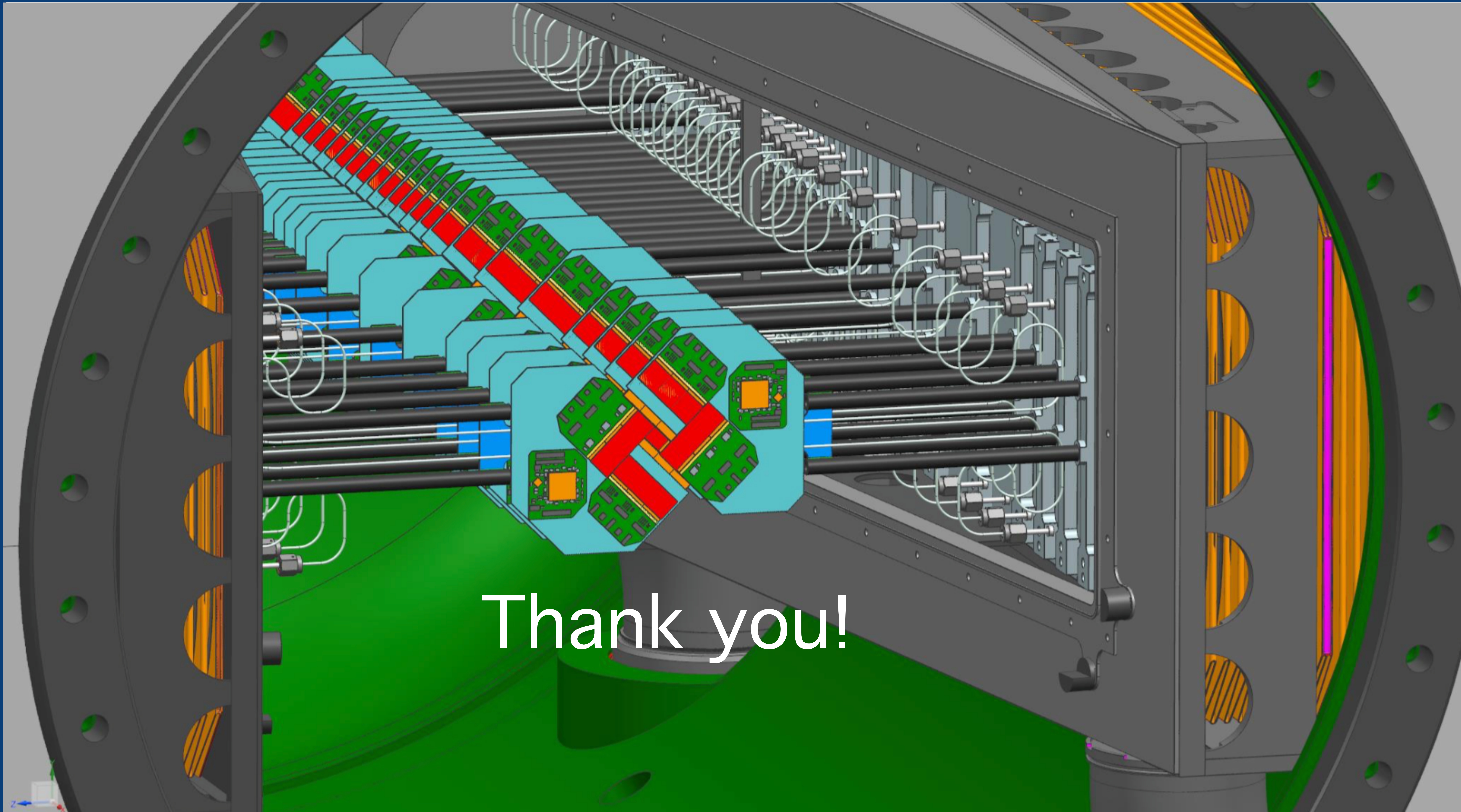
Microchannel cooling is the cooling solution to be used by the VELO Upgrade.

DAQ structure for the VeloPix control and readout are now in place.

VELO Module Production should start June-July.

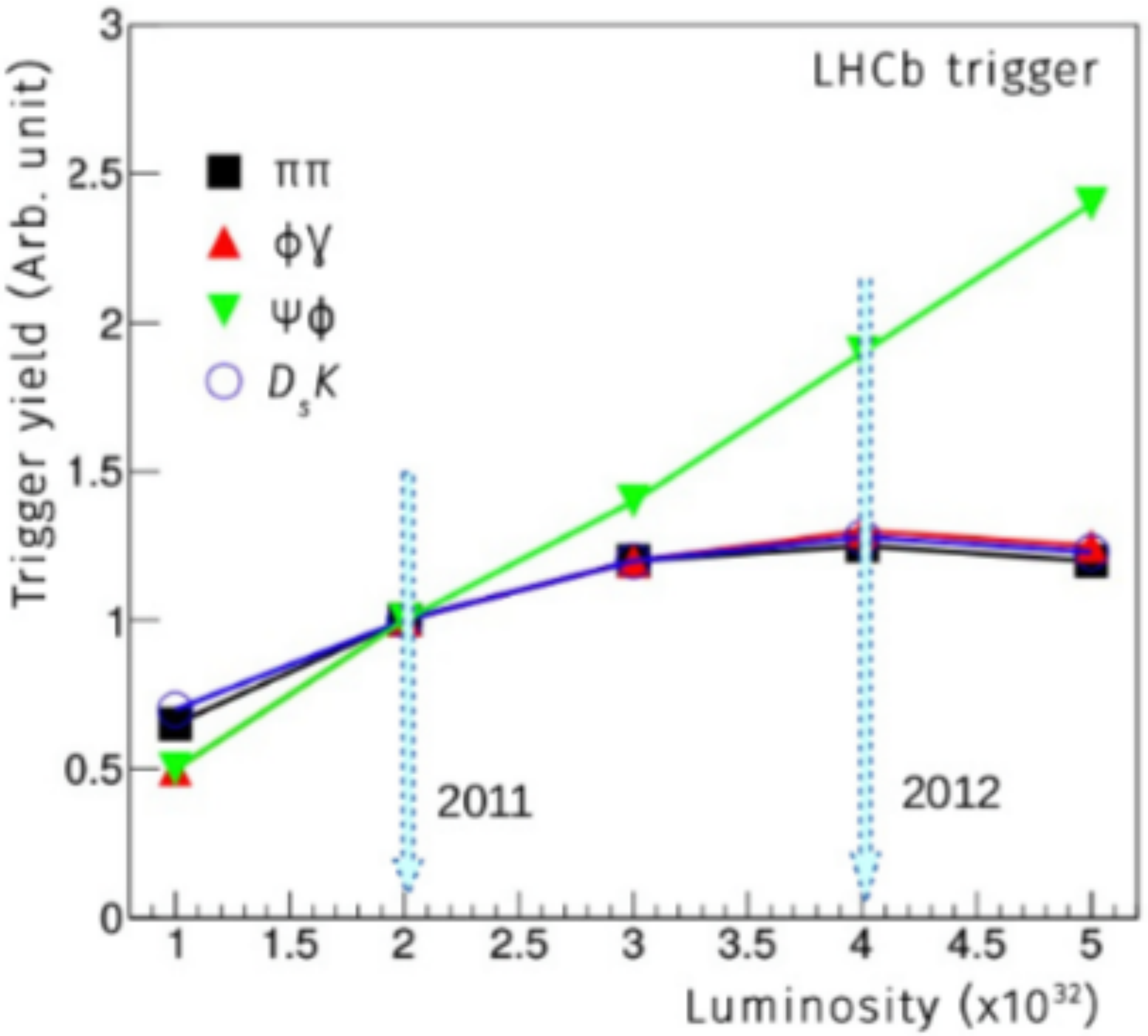
Bump Bonding of Sensors to VeloPix ASICS currently on pre-production.

First data taking after LS2 in 2021!


Thank you!

Backup

LHCb Detector Upgrade



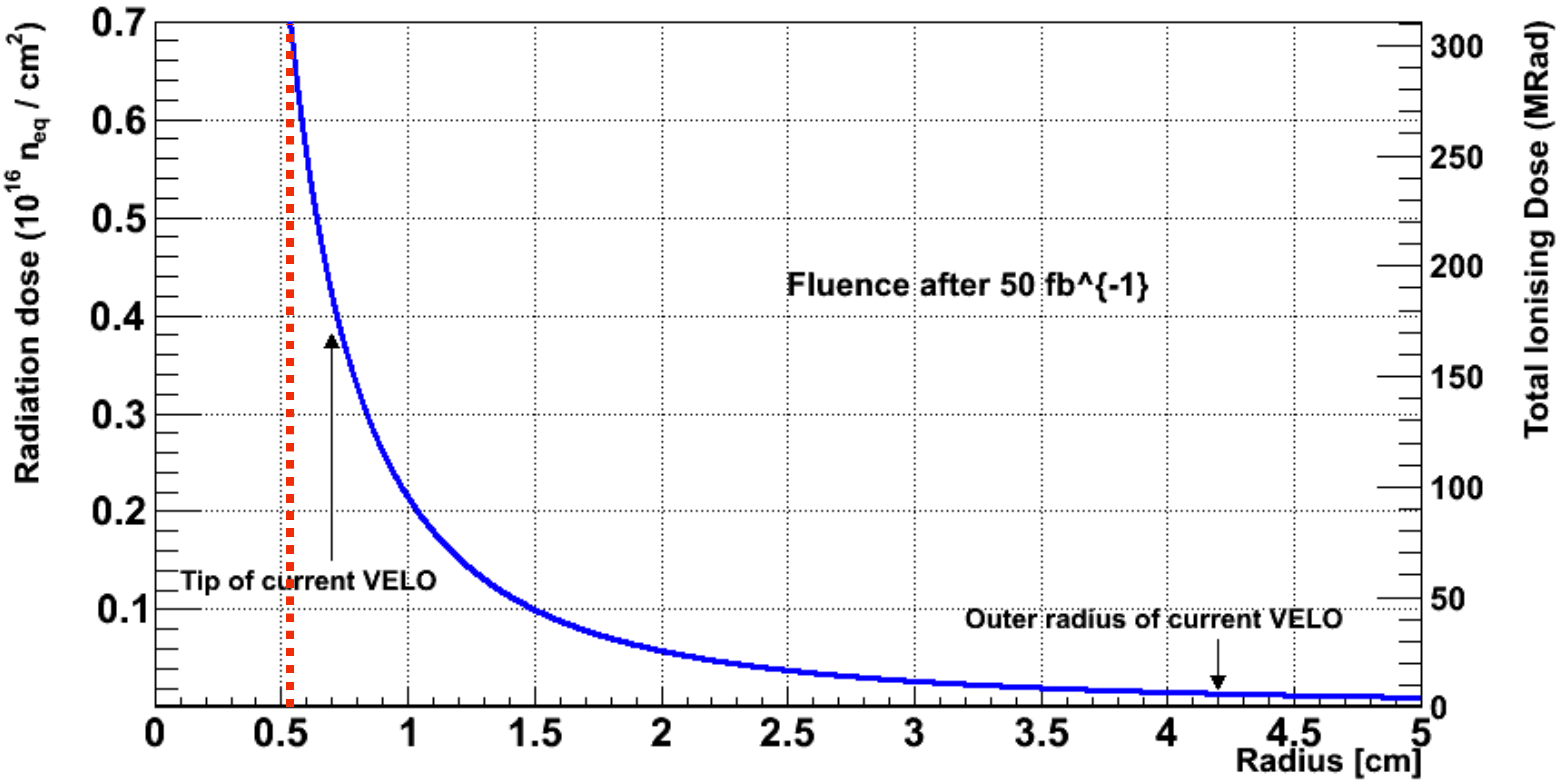
By the end of Run II many analysis become statistically limited.

Increasing Luminosity in order to achieve $50fb^{-1}$ in Run III.

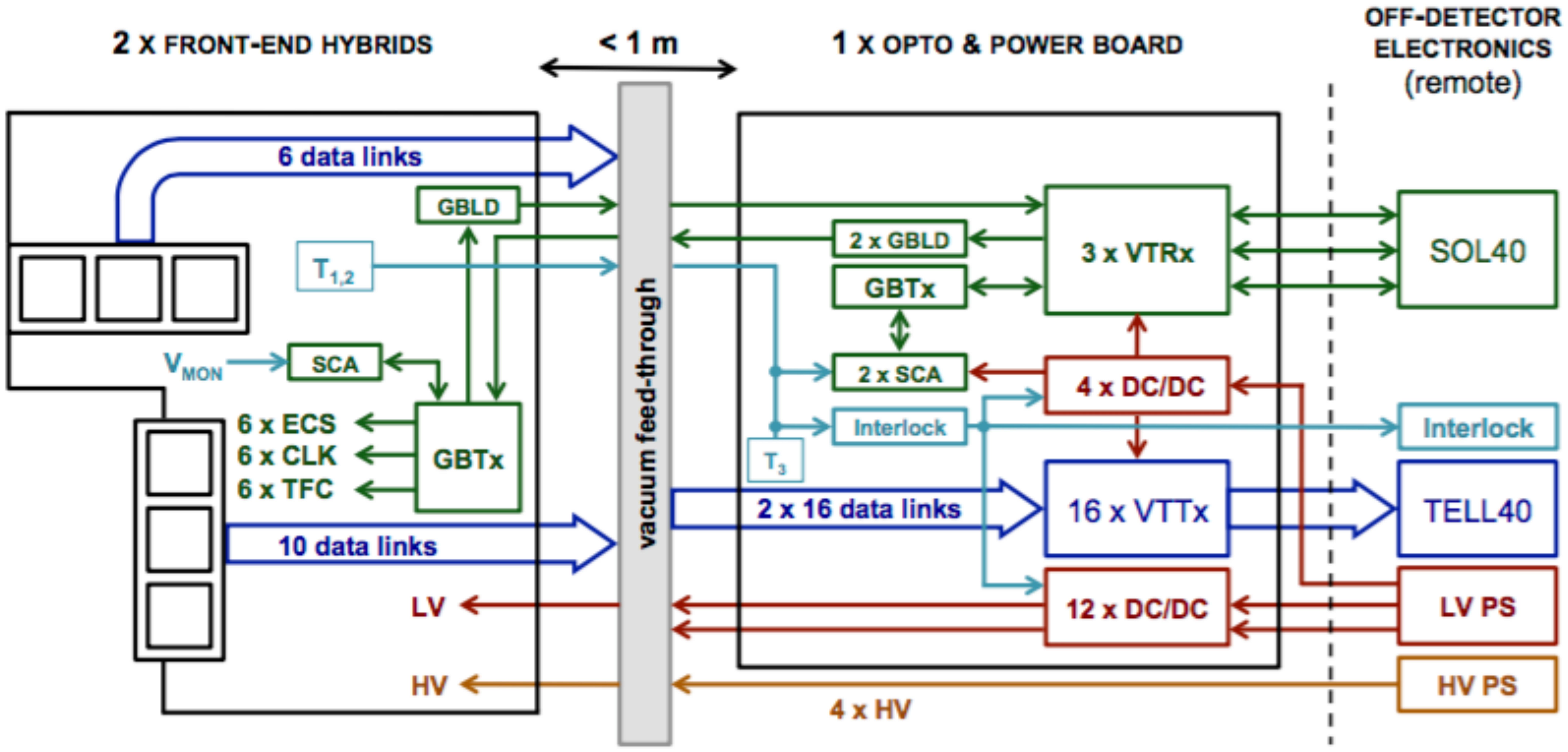
$4x10^{32}$ $cm^{-2}s^{-1}$ → $2x10^{33}cm^{-2}s^{-1}$

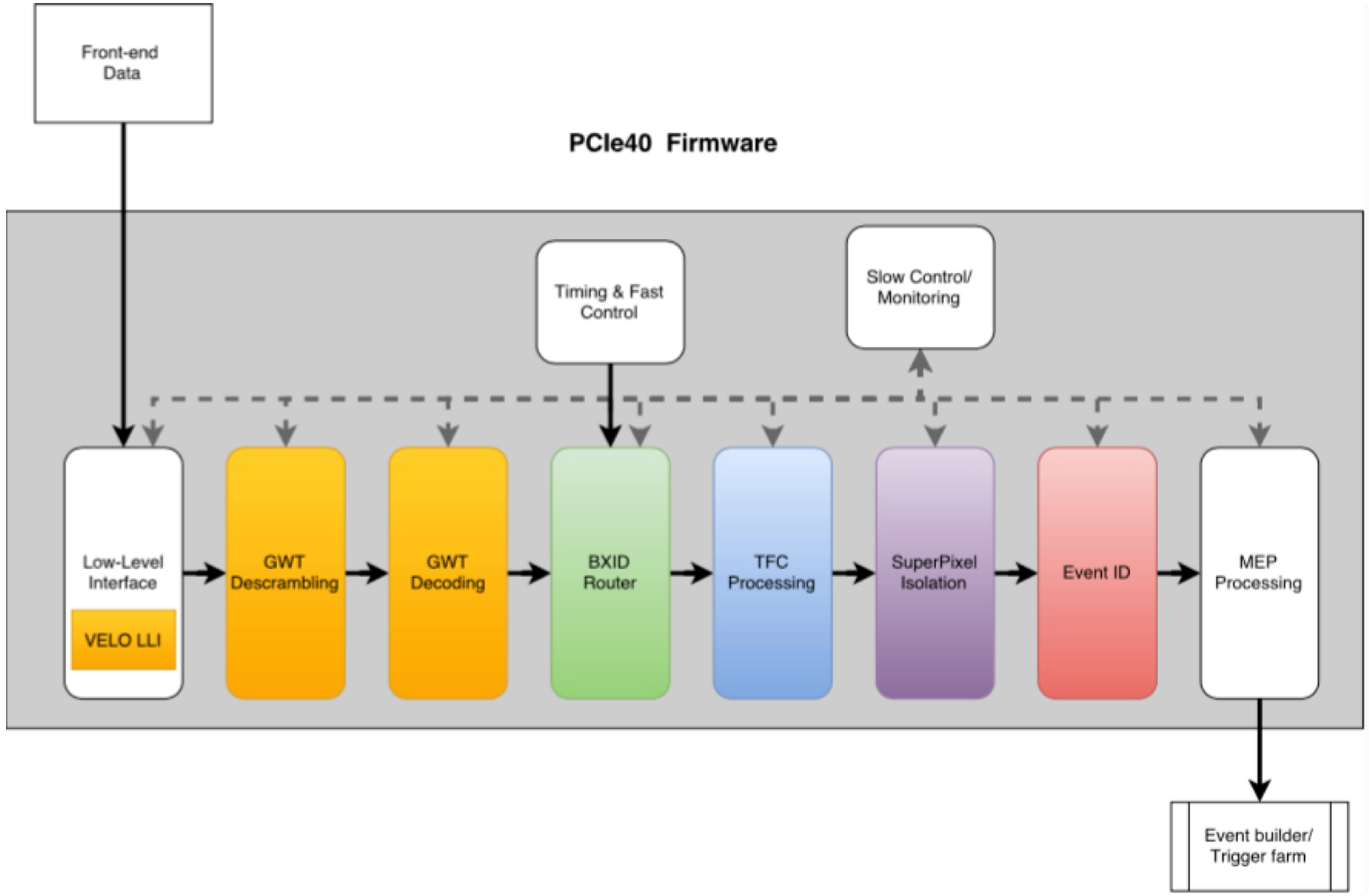
Upgrade Trigger implemented on software only.

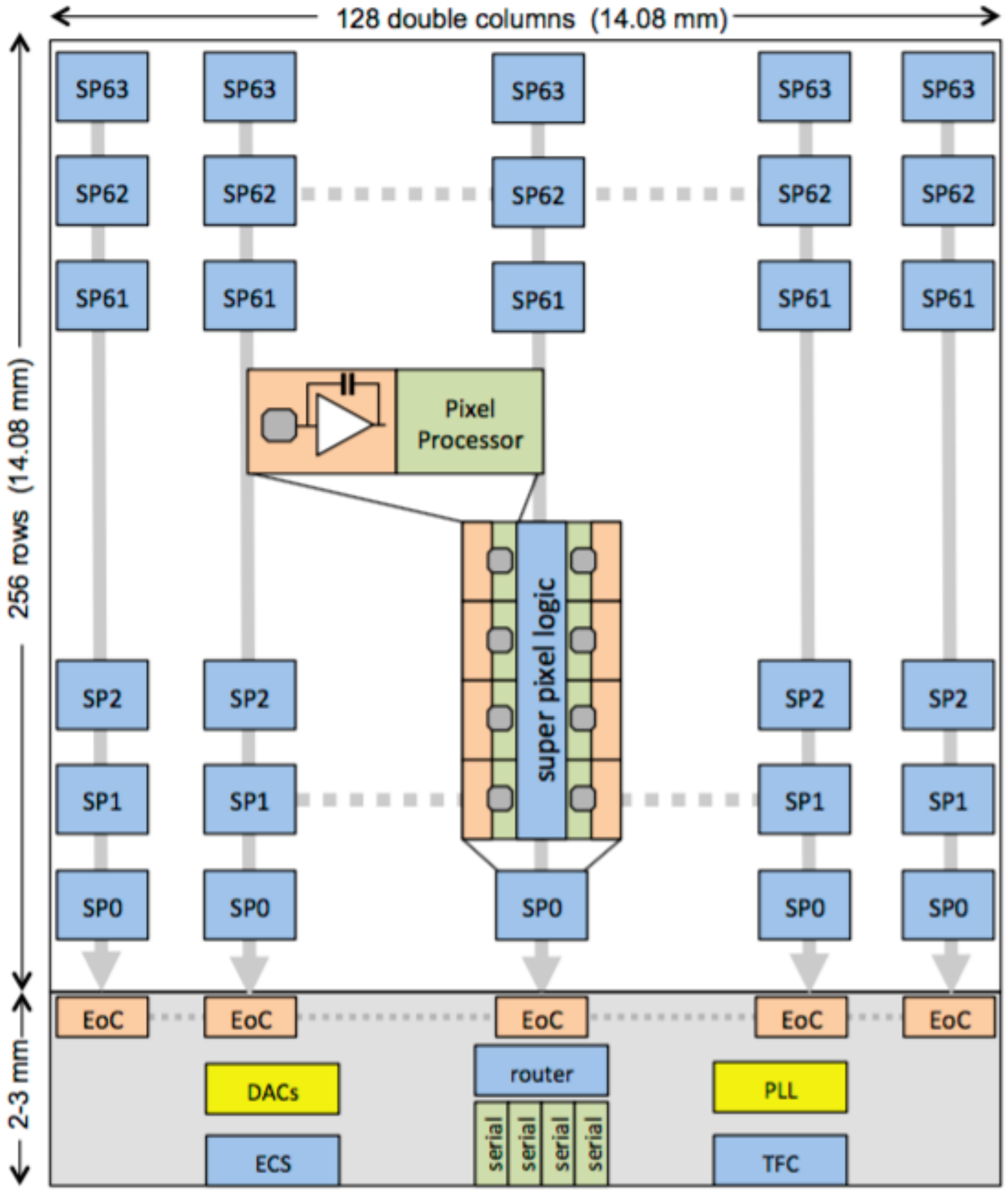
Readout: 1 MHz → 40 MHz



Radiation dose (10^{16} n_{eq} / cm^2)
Total Ionising Dose (MRad)
Fluence after 50 fb^{-1}
Tip of current VELO
Outer radius of current VELO
Radius [cm]
0.7
0.6
0.5
0.4
0.3
0.2
0.1
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

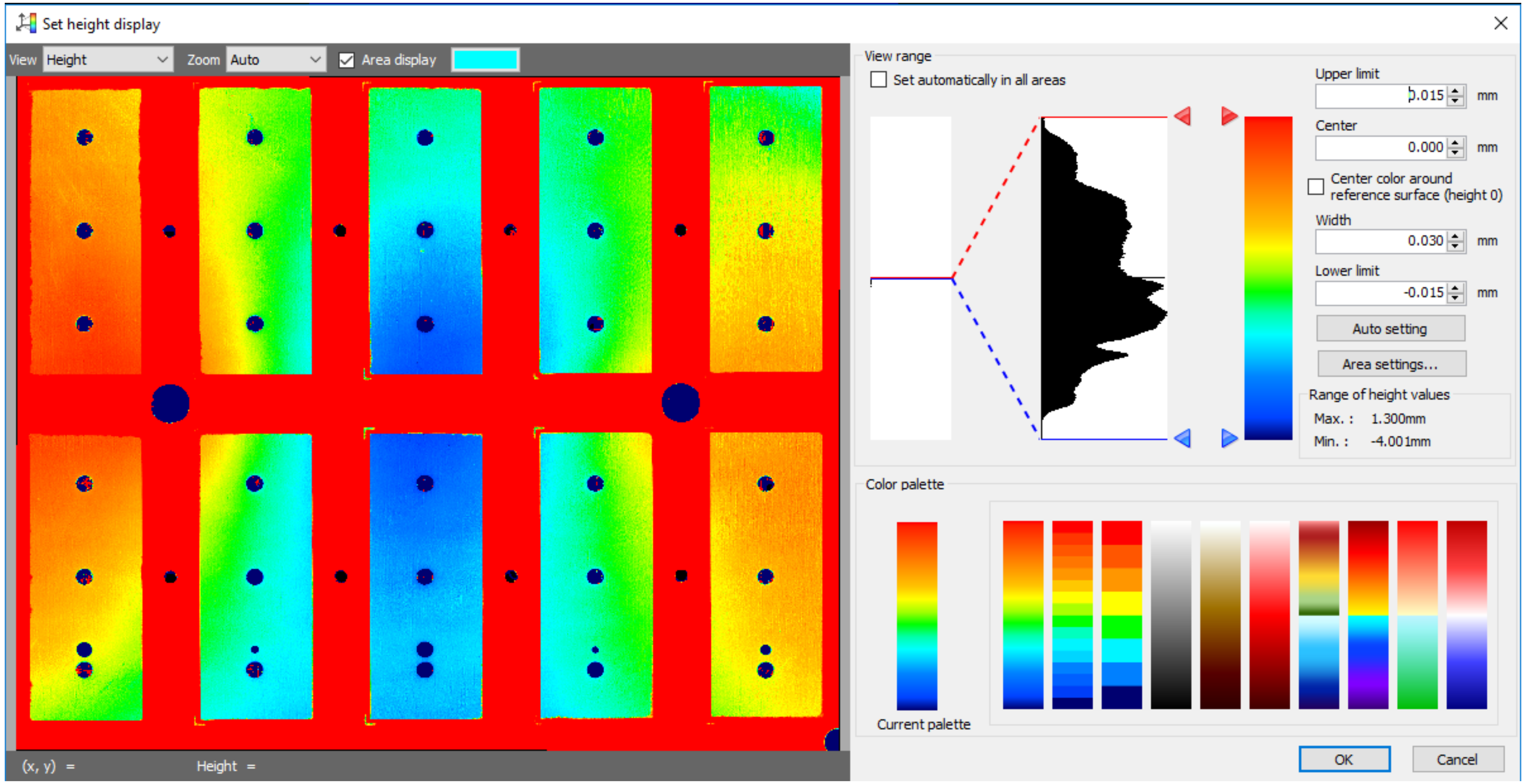

2 X FRONT-END HYBRIDS
< 1 m
1 X OPTO & POWER BOARD
OFF-DETECTOR ELECTRONICS (remote)
6 data links
GBLD
$T_{1,2}$
V_{MON}
SCA
6 x ECS
6 x CLK
6 x TFC
GBTx
10 data links
LV
HV
vacuum feed-through
2 x GBLD
GBTx
2 x SCA
Interlock
T_3
3 x VTRx
4 x DC/DC
16 x VTTx
2 x 16 data links
12 x DC/DC
4 x HV
SOL40
Interlock
TELL40
LV PS
HV PS


Front-end Data
PCIe40 Firmware
Timing & Fast Control
Slow Control/ Monitoring
Low-Level Interface
VELO LLI
GWT Descrambling
GWT Decoding
BXID Router
TFC Processing
SuperPixel Isolation
Event ID
MEP Processing
Event builder/ Trigger farm


128 double columns (14.08 mm)
256 rows (14.08 mm)
2-3 mm
SP63
SP62
SP61
Pixel Processor
super pixel logic
SP2
SP1
SP0
EoC
DACs
ECS
router
serial
PLL
TFC

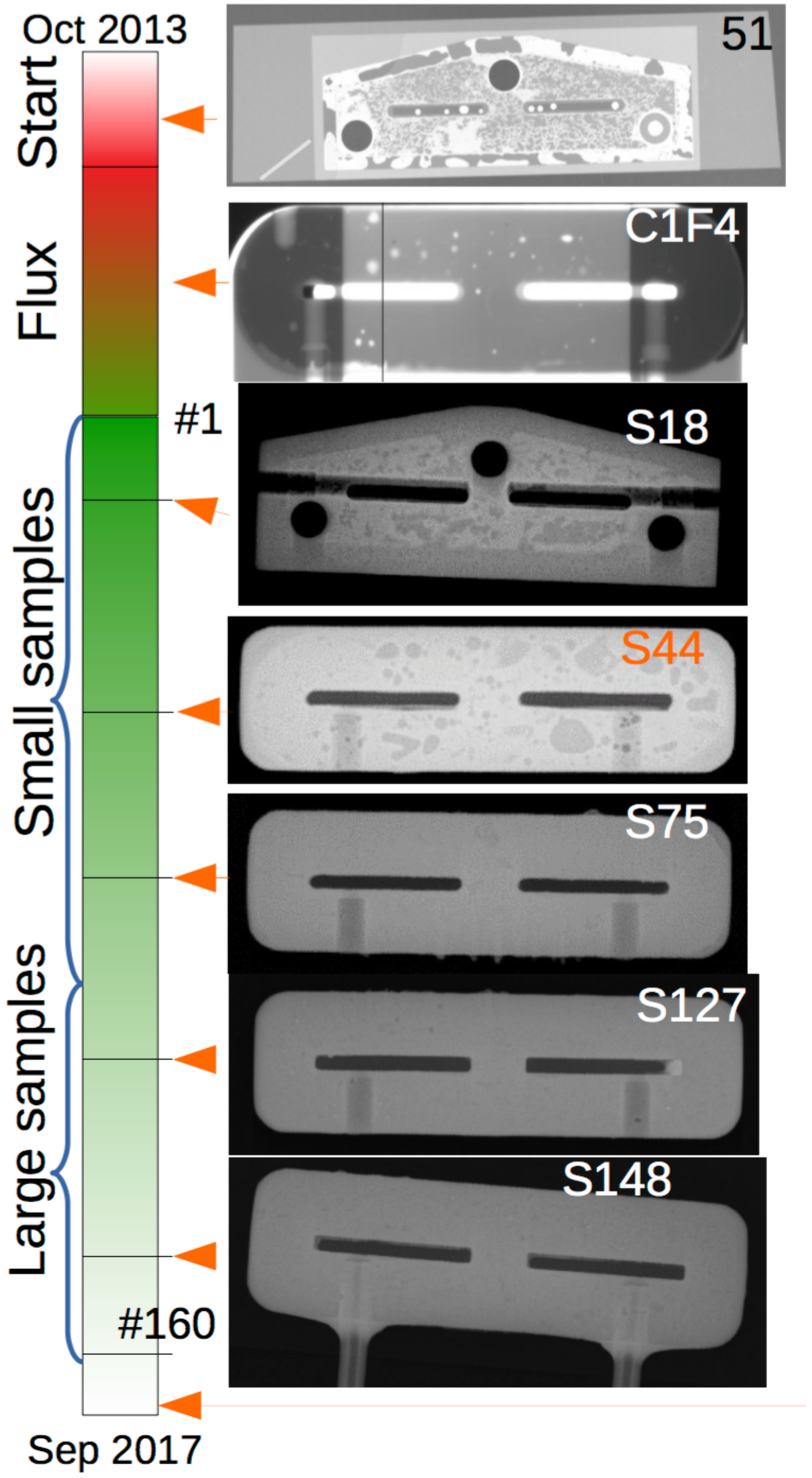
QA

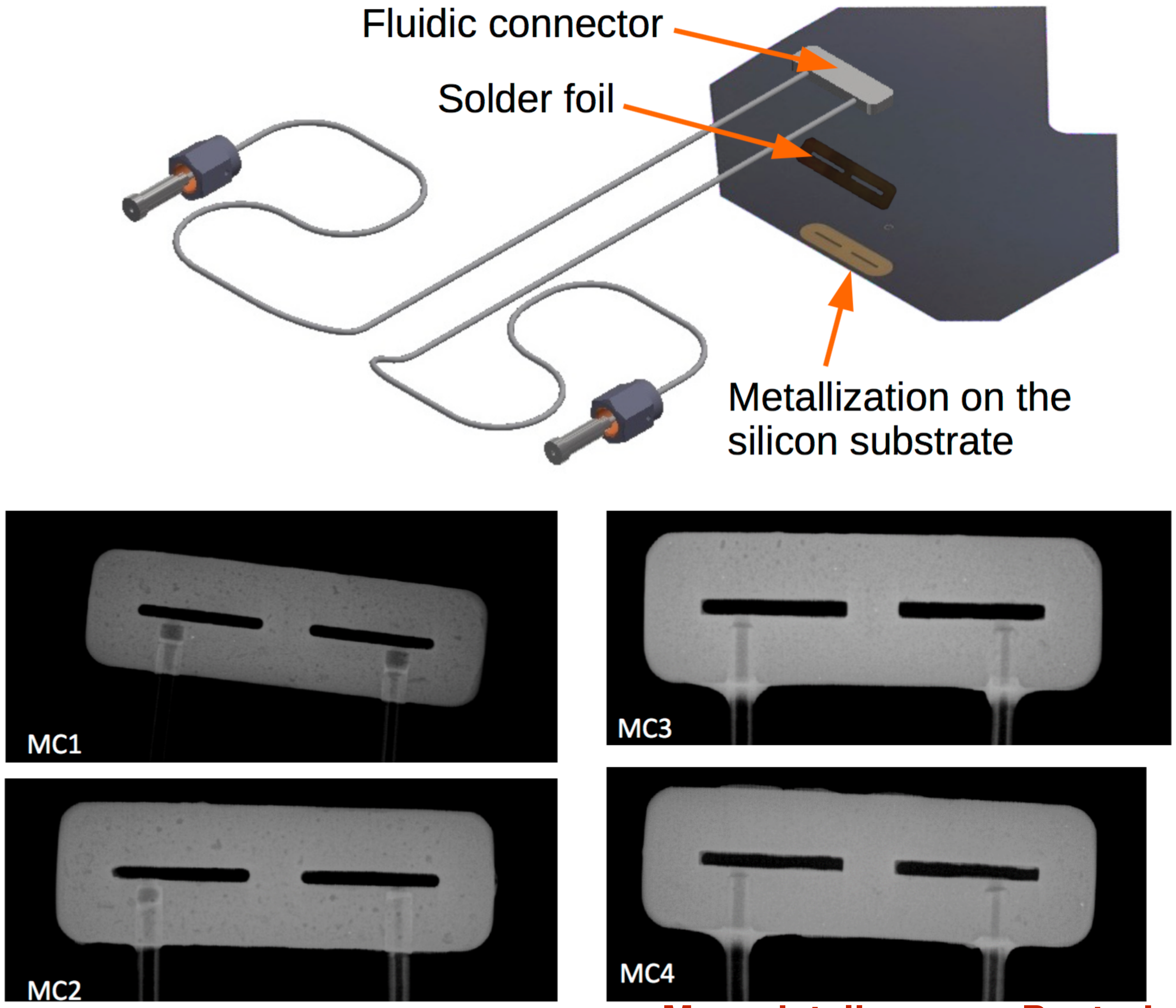
- Check the flatness of the surface using the white light interferometer.



Overall height variation of 30 um over the whole surface.

Cooling





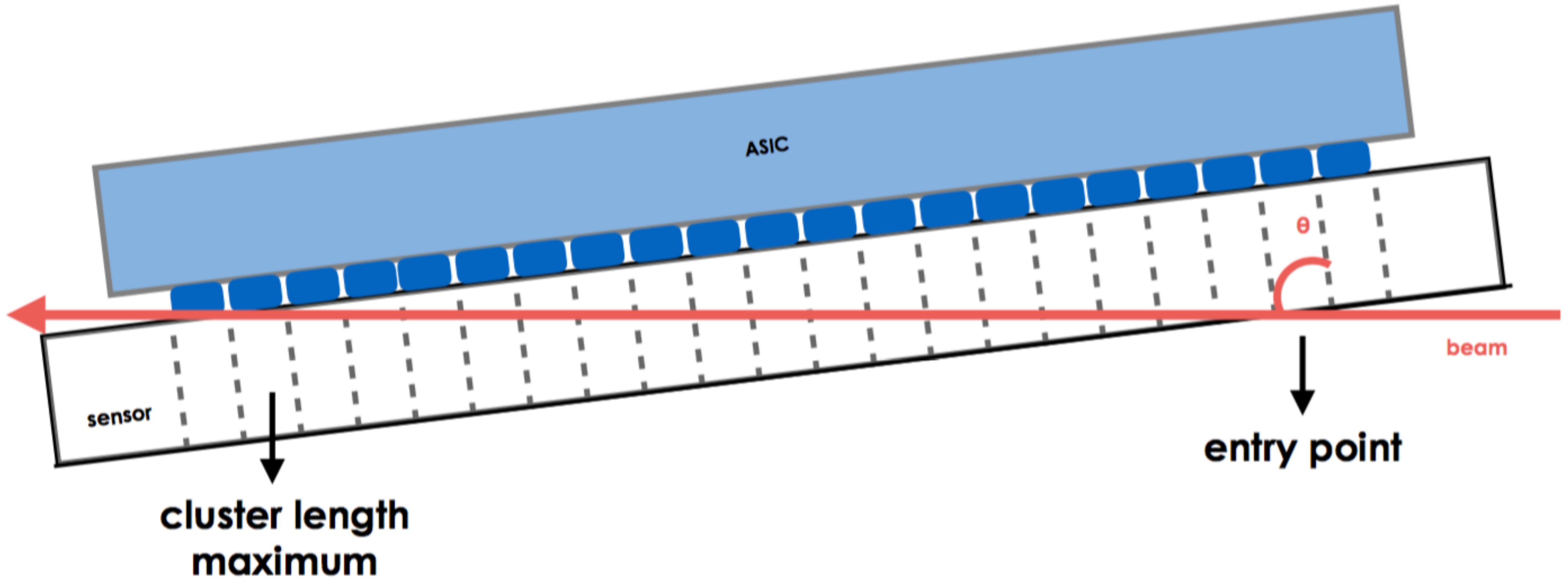
More details on my Poster!

Charge Collection and Depletion Depth

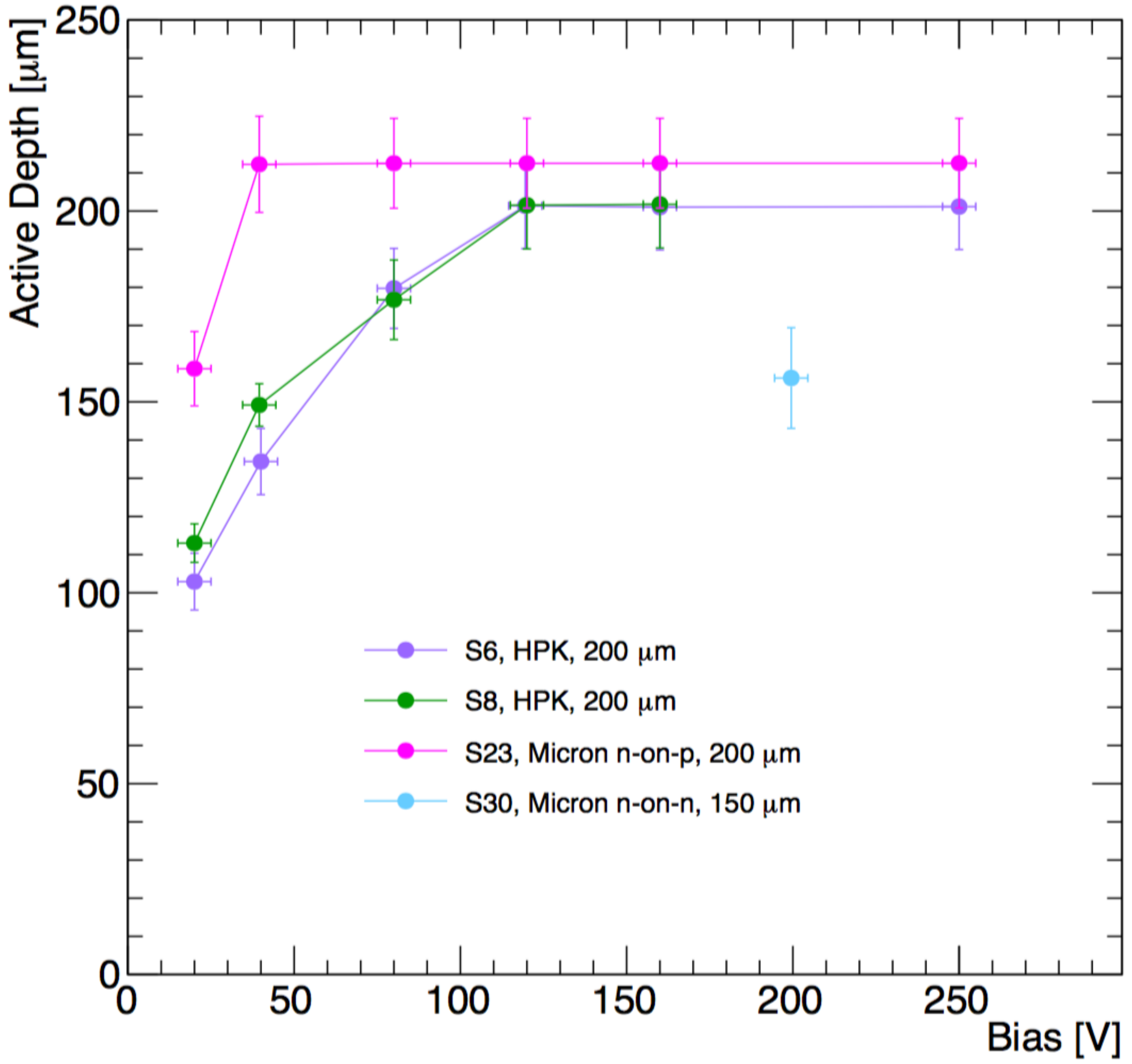
Determined using Grazing Angle Technique.

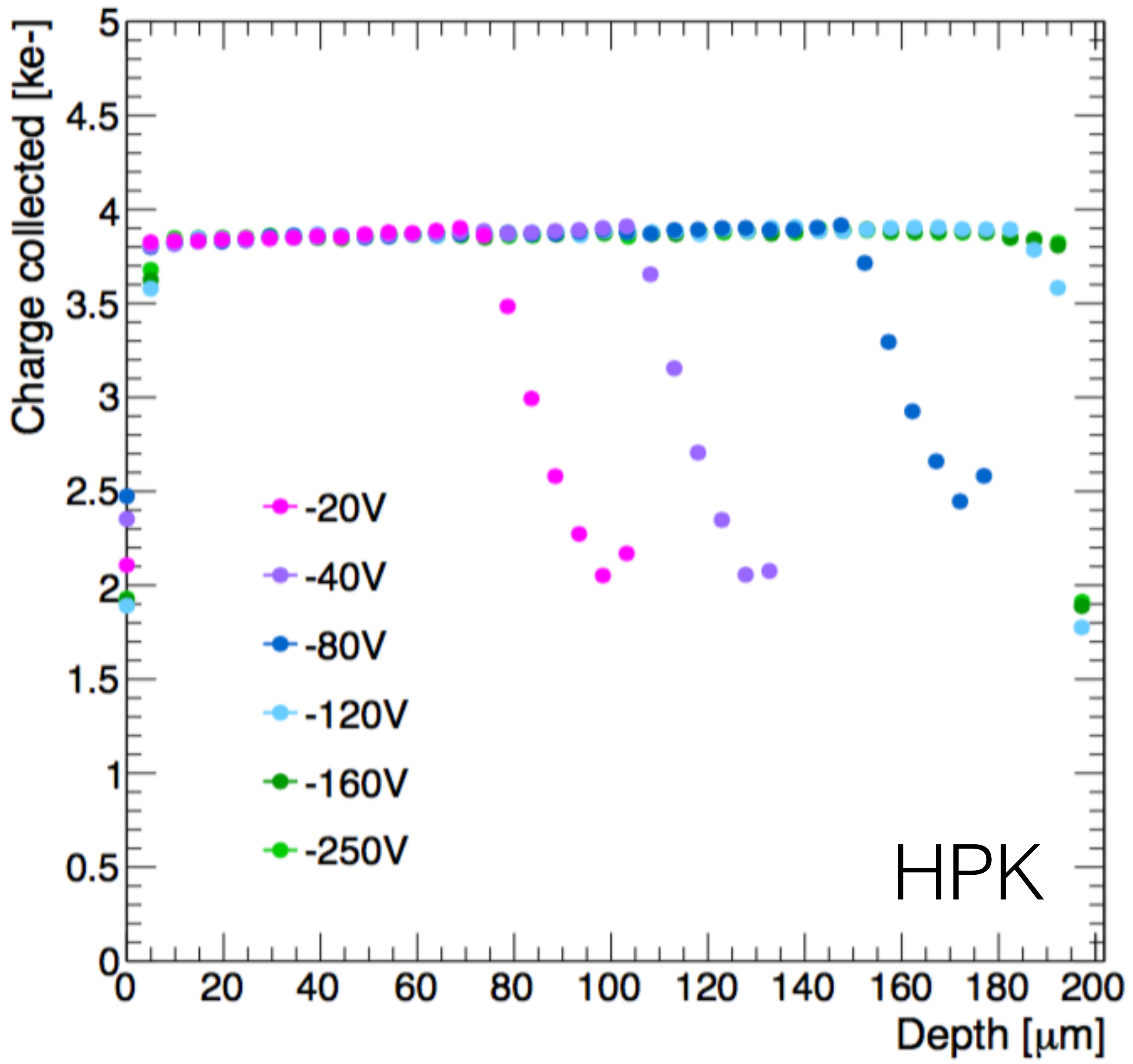
DUT clusters associated with a track if within a 10 ns window.

Correction for Timewalk effect is applied using charge collection time of tracks passing wishing 20µm of implants



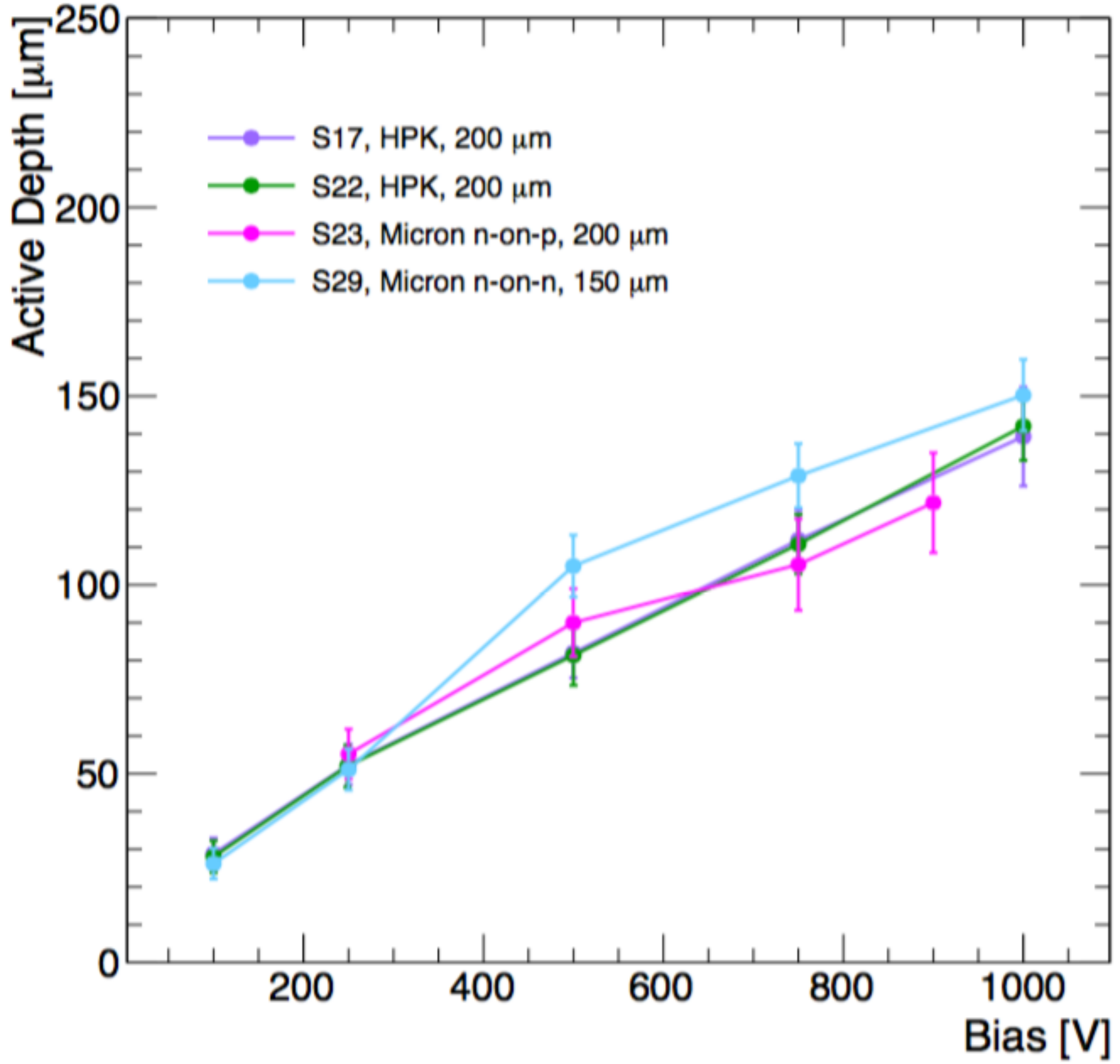
Non irradiated sensors

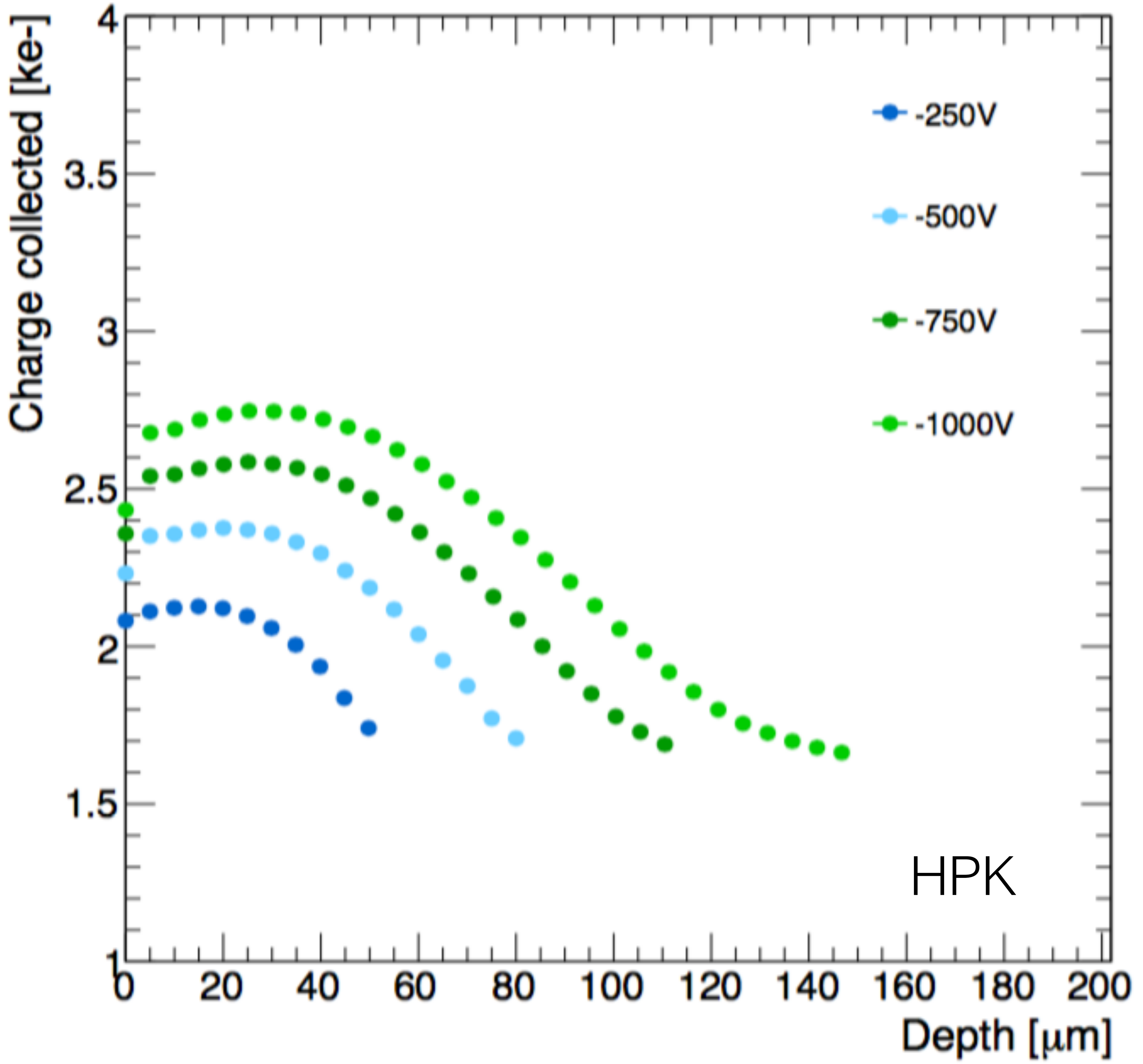




Charge Collection and Depletion Depth

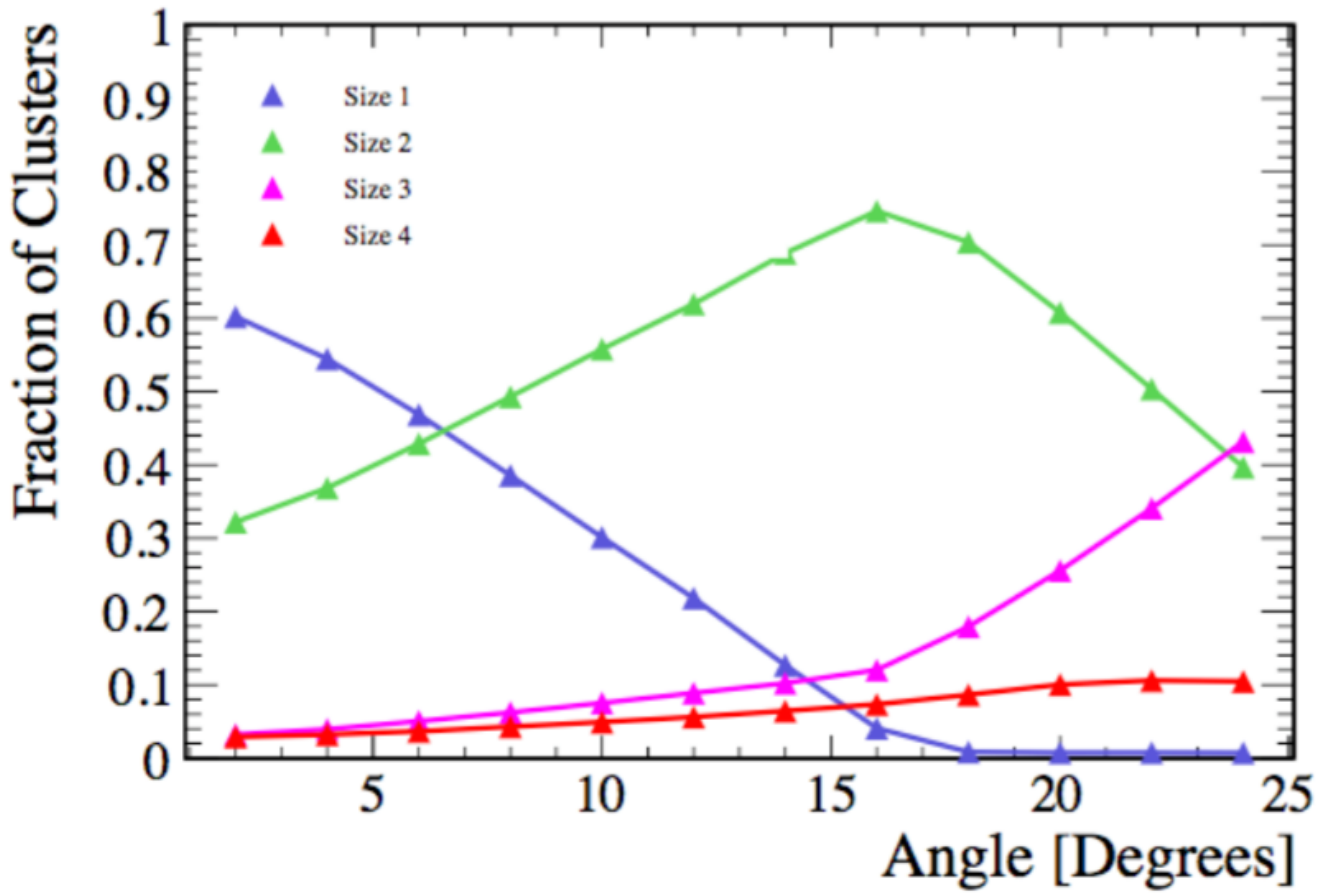
Neutron Uniformly Irradiated to Full Fluence

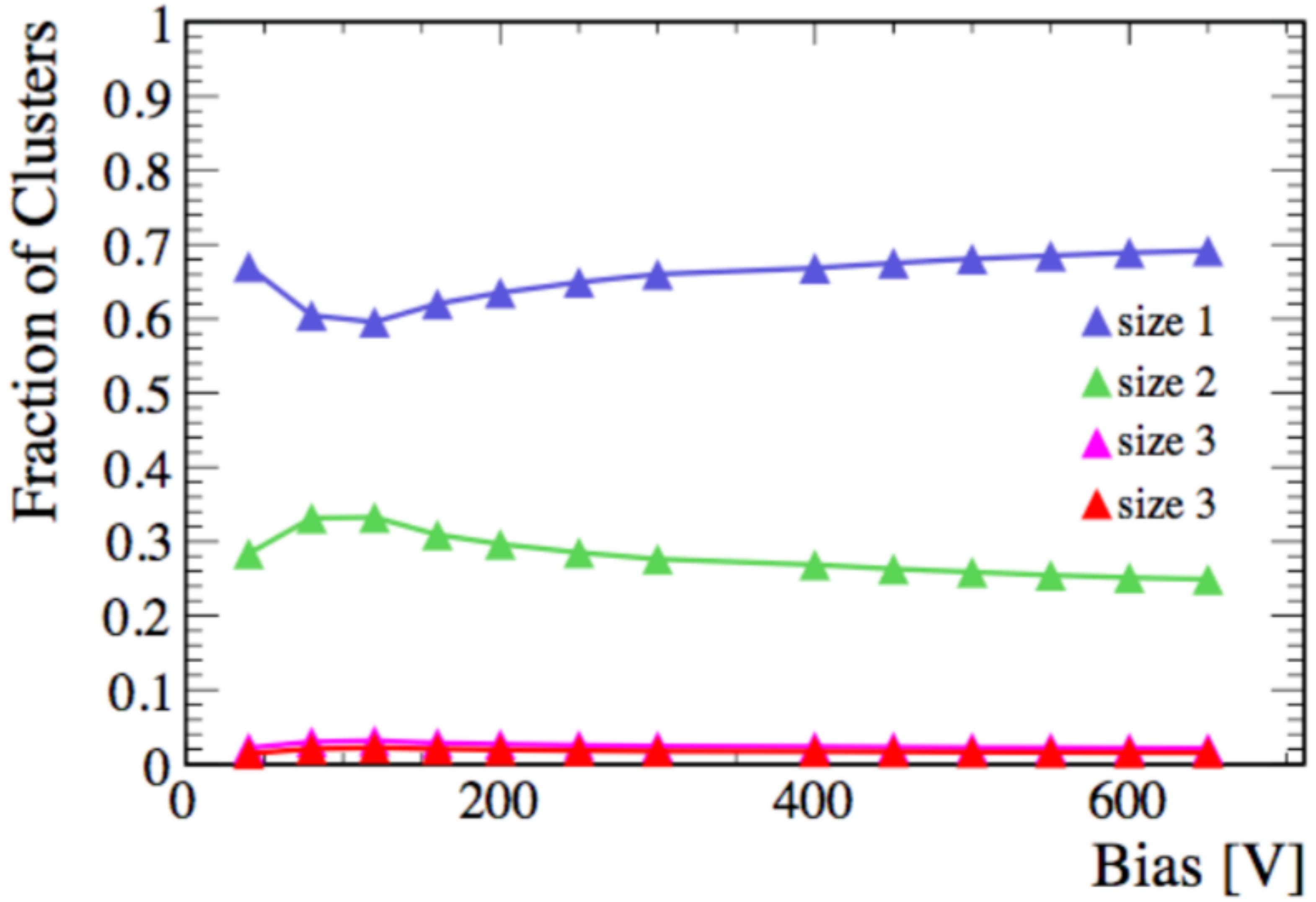




Cluster Sizes Distributions

Non-Irradiated
Micron n-on-p





Post Irradiation
Micron n-on-p